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HATCHERY PRODUCTION AND REFORM IN THE COLUMBIA CASCADE PROVINCE: A LANDSCAPE PERSPECTIVE

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INTRODUCTION

Wild salmon and steelhead populations (hereafter often referred to simply as "salmon") of the Columbia River Basin have been unfavorably affected by historic habitat degradation and loss, hydrosystem development, over-fishing, and artificial propagation (hatchery) programs focused primarily on supporting harvest in various fisheries. The result has been the extinction of many runs of these fish (Nehlsen et al. 1991), Endangered Species Act (ESA) listings for others, and diminished productivity for most of those runs that have not declined to a degree sufficient to warrant listing. Today, annual salmon runs up the Columbia River average perhaps a million fish where once there were about ten million or more, and fish produced in hatcheries dominate the returns to much of the basin. Clearly written discussions of the decline in salmon abundance, the causative factors, and efforts to reverse them, can be found in multiple reviews that include those by the National Research Council (NRC 1996) and the Independent Scientific Group (ISG 2000). Hatchery production of salmon, which began in the late 1800s, and became more effective in the late 1950s and early 1960s at returning adult fish to the river, has failed to maintain or replace the diversity and abundance of salmon once present (Figure 1).

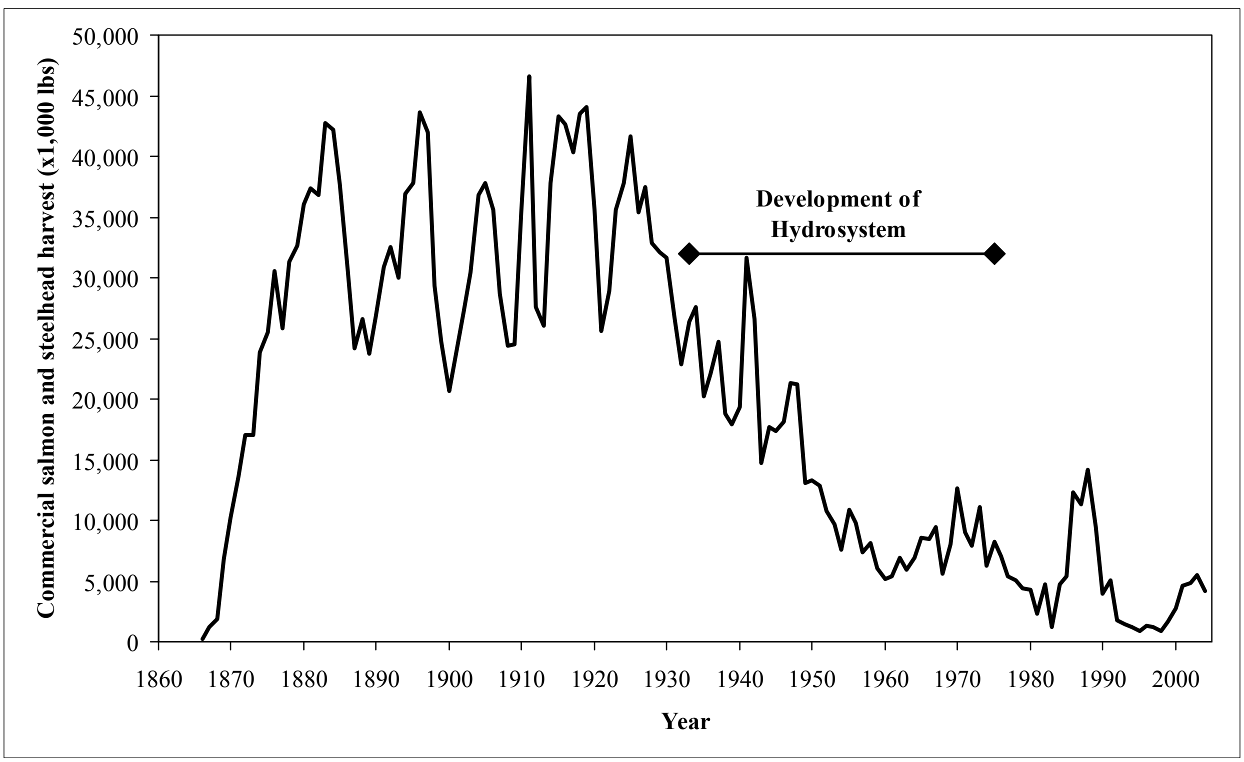


Figure 1. Five year running average of Chinook salmon harvest in thousands of pounds in the Columbia River, 1866 to 1992, with the average harvest for four periods of development. Sources: ISG (2000), Williams et al, 2003, and IEAB 2005.

Dwindling runs of wild salmon, concern that fish hatchery programs have not helped to reverse deeply embedded trends, and a growing body of evidence that the presence of conventionally produced and managed hatchery salmon have contributed to the losses of wild fish, have led to calls for hatchery reform. The consensus that seems to have developed is that there clearly are roles for hatcheries in the management of salmon, but that these roles need to be more precisely defined, sensitive to the needs of at-risk populations of the fish, reflected in programmatic changes in the hatchery system, and adhered to by those managing hatchery facilities.

With regard to ongoing salmon restoration efforts, and specifically to such efforts in the Columbia River Basin (CRB), one role that has been identified for salmon hatcheries is that they may provide key temporary refuges for some populations in upper portions of the basin while causes of elevated downstream mortality associated with the hydrosystem are remedied (Bowles 1995; Waples 1999). The NRC (1996), noting obligations to American Indian tribes whose fisheries have been severely diminished, suggested that there may be a need for long-term catch augmentation hatcheries managed (and presumably sited) so as to separate hatchery fish from naturally spawning fish in freshwater habitats and to allow capture of these fish without imposing added harvest pressures on wild populations. Consistent with these perspectives but more broadly stated, hatcheries need to be used cautiously in ways that meld their operations into restoration strategies focused on landscapes, watersheds, aquatic habitat, and conserving the genetic and life-history diversity found in natural salmon populations (e.g., White et al. 1995; Allendorf and Waples 1996; NRC 1996; SRT 1999; HSRG 2004). Summarizing this view and suggesting multiple aspects of where its application might lead, Williams et al. (2003), in a white paper prepared for Trout Unlimited, suggested that hatcheries be managed with a "landscape perspective".

The following report was prepared as a follow-up to Williams et al's (2003) white paper suggesting the strong need for a landscape perspective in hatchery management, and for major reconfigurations of programs if the hatchery "tool" is to help conserve declining populations of salmon. It was initially conceived to provide a broad overview of the programs operating and under reform in the CRB, and then to look more closely at hatchery programs in the basin's Columbia Cascade Province to suggest how those operated by the U.S. Fish and Wildlife Service (USFWS) might be modified to become landscape focused. However, as the report was developed it became apparent that the real question in the Columbia Cascade Province (and likely elsewhere) was not how individual hatcheries or programs might be reformed in isolation, but how the aggregate of all hatchery programs within the area might be reformed together so as to achieve a suite of specific societal objectives. As a result, the report which follows stops short of making explicit and detailed recommendations for the USFWS programs. Instead, it provides a context for changes to be made in these programs and information intended to be helpful to Trout Unlimited as it formulates recommendations for such changes.

The report is broken into sections that address multiple questions about hatchery programs in the CRB and the Columbia Cascade Province. These include:

- How many fish of each species of salmon are produced by these programs, and in which geographic areas?
- What kinds of hatchery programs are producing these fish and how are those programs intended to be managed?
- What are the concerns about natural spawning by hatchery-origin salmon?
- What is the state of the natural salmon populations, and of the hatchery programs associated with them, in the Columbia Cascade Province?
- How generally might the USFWS hatchery programs in the Columbia Cascade Province be modified to become more consistent with the landscape-based management perspective recommended by Williams et al. (2003)?

RELEASES OF HATCHERY SALMON IN THE COLUMBIA RIVER BASIN

Fish hatcheries in the Columbia River Basin (CRB) annually release large numbers of juvenile Chinook salmon (spring, summer, and fall-run), coho salmon, and steelhead, plus smaller quantities of young sockeye and chum salmon. Basin-wide production of hatchery salmon has increased from about 75 million in 1960 to as many as 250 million juvenile fish in the late 1980s, and has recently decreased to less than 150 million after concerns were raised that their abundance in combination with less-abundant wild juvenile salmon might well be exceeding environmental capacity, particularly in the Columbia River estuary (Figure 2). The decrease in basin-wide hatchery production since the 1980s has been substantial (an ~35% drop from an annual average of 219.7 million juvenile fish during 1986-90 to an average of 142 million in 2001-05) and effected most strongly by reduced releases of fall Chinook and coho salmon into the Lower Columbia Basin downstream of Bonneville Dam. Trends in the total numbers of hatchery salmon produced and released farther upstream in the CRB since 1960 have varied by location, ranging from erratic declines to substantial increases. However, increased hatchery releases have been common in many upper basin areas as policy makers and fish managers have attempted to mitigate declines and losses of salmon in the areas most strongly affected by the Columbia River hydrosystem.

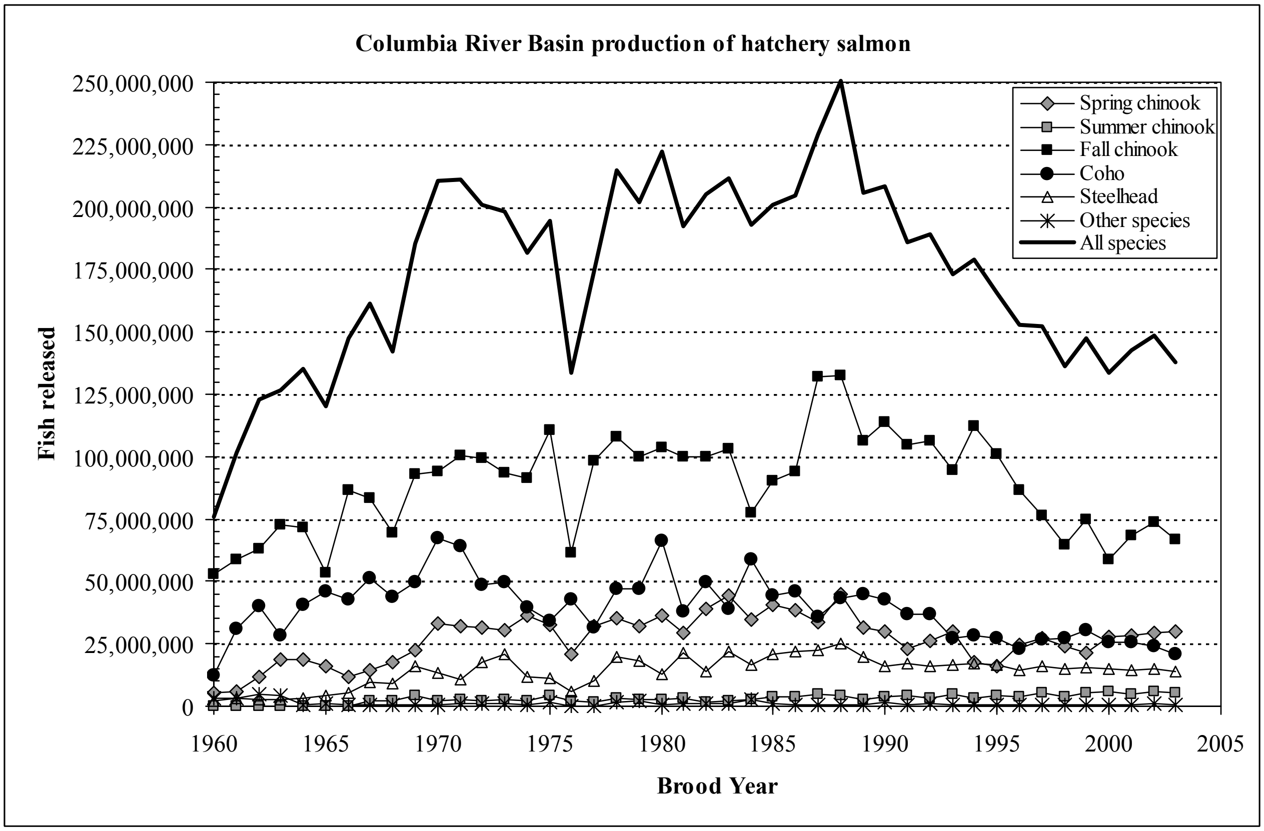


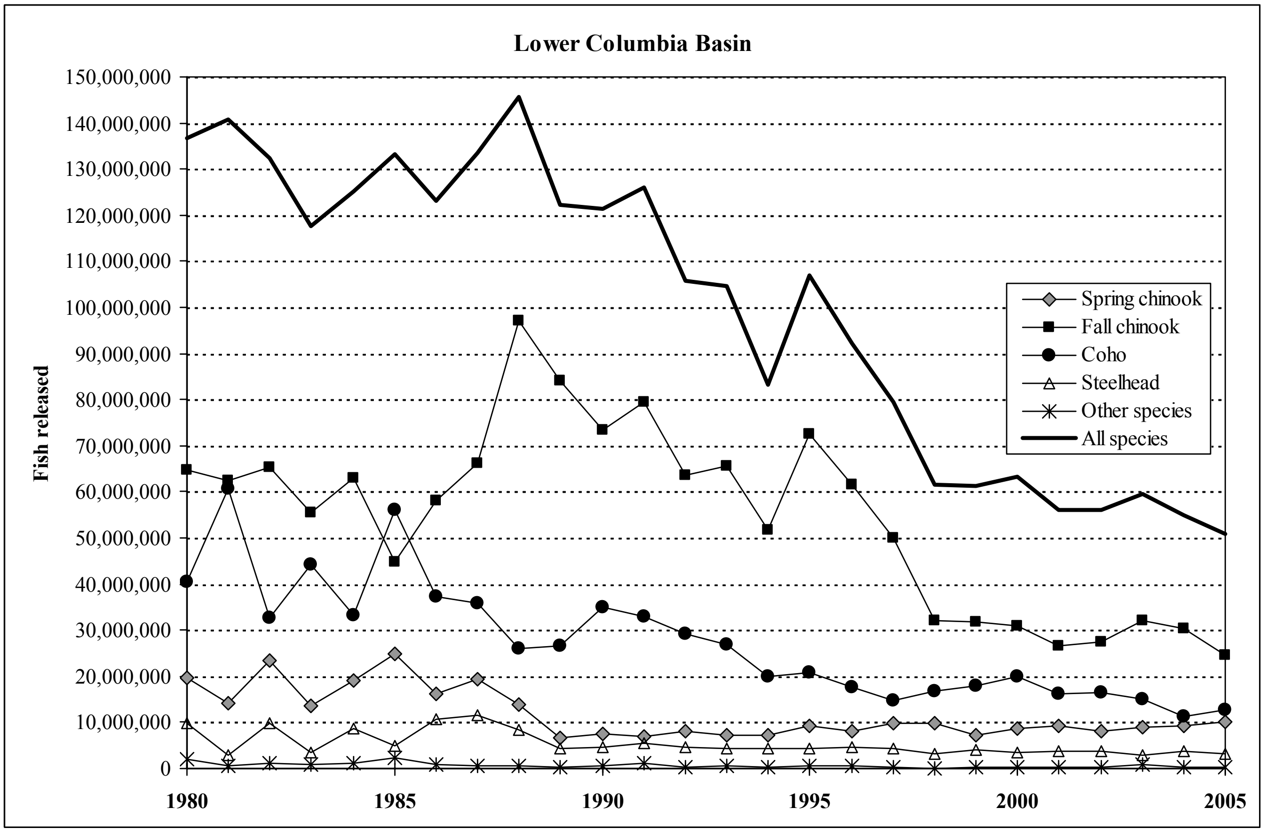
Figure 2. Releases of hatchery salmon (as juveniles) in the Columbia River Basin, brood years 1960-2003. Sources: Palmisano et al. (1993) and the Fish Passage Center.

Lower Columbia Basin. Despite declining hatchery releases over the last 25 years, the drainage basin downstream of Bonneville Dam remains the most heavily planted receiving area for juvenile hatchery salmon in the CRB (Figure 3). This reflects an historic emphasis on constructing hatcheries and producing hatchery salmon in areas where their returns to fisheries could be maximized. Annual hatchery releases of salmon into this basin include spring and fall Chinook, coho salmon, steelhead, sea-run cutthroat trout, and chum salmon. Annual releases here during 2001-2005 averaged approximately 55.5 million fish, 58% fewer than the average of 132 million fish released during a peak in hatchery production experienced during 1984-1988.

Middle Columbia Basin. Annual hatchery releases into the drainage basin between Bonneville Dam and the Columbia-Snake River confluence totaled about 34.6 million juvenile salmon annually during 2001-2005, 23% fewer fish than the average of 45 million that were released here annual during a 1990-1994 peak in hatchery production (Figure 3). Recent hatchery releases into the basin's waterways have included spring Chinook, fall Chinook, coho salmon, and steelhead. The recent decline in numbers of hatchery fish released within the basin has been most pronounced for fall Chinook, but has been observed in spring Chinook and coho releases as well.

Upper Columbia Basin. In the Upper Columbia Basin, upstream of the Columbia-Snake River confluence, total releases of juvenile hatchery fish have nearly doubled since 1980, largely as a consequence of increased annual releases of sub-yearling fall Chinook (Figure 4). Hatchery releases of spring Chinook, summer Chinook, coho salmon, steelhead, and sockeye have changed less here during the past 25 years (i.e., since 1980), although releases of summer chinook have increased somewhat, and those of spring chinook have fluctuated noticeably since 1990. Total annual hatchery releases of juvenile salmon into the basin averaged about 23 million fish during 2001-2005.

Snake Basin. Releases of hatchery salmon into waterways of the Snake Basin averaged 24.8 million during 2001-2005, more than double the size of releases seen back in 1980, but remain dominated by juvenile spring chinook and summer steelhead (Figure 4). The numbers of steelhead released annually into the area have been far more stable than have those of spring Chinook, due to erratic and often very low smolt-to-adult return rates to hatcheries for the later species. Spring Chinook at the hatcheries were not consistently replacing themselves in the 1990s. Unlike the Lower, Middle, and Upper Columbia basins, total releases of hatchery salmon in the Snake Basin are dominated by yearling fish (spring Chinook and summer steelhead smolts) and not sub-yearling fall Chinook salmon.



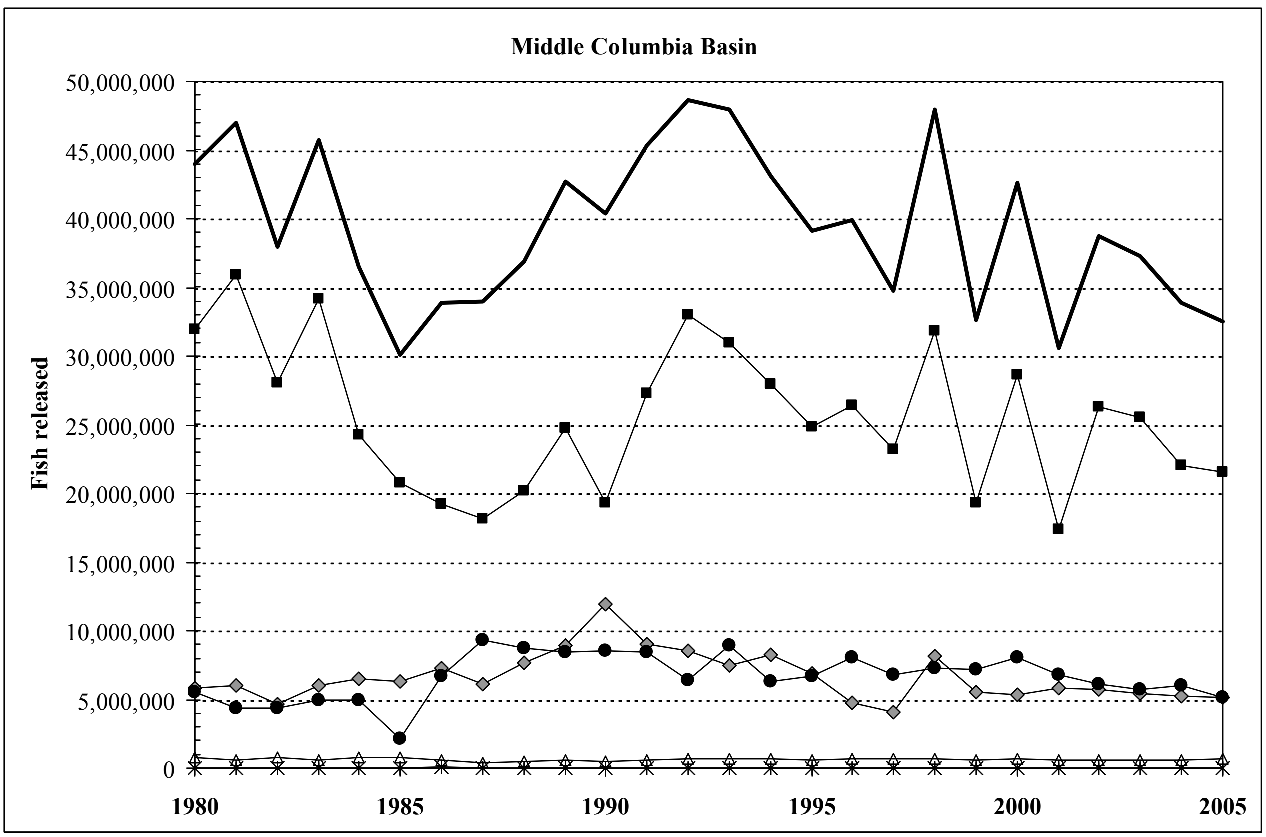
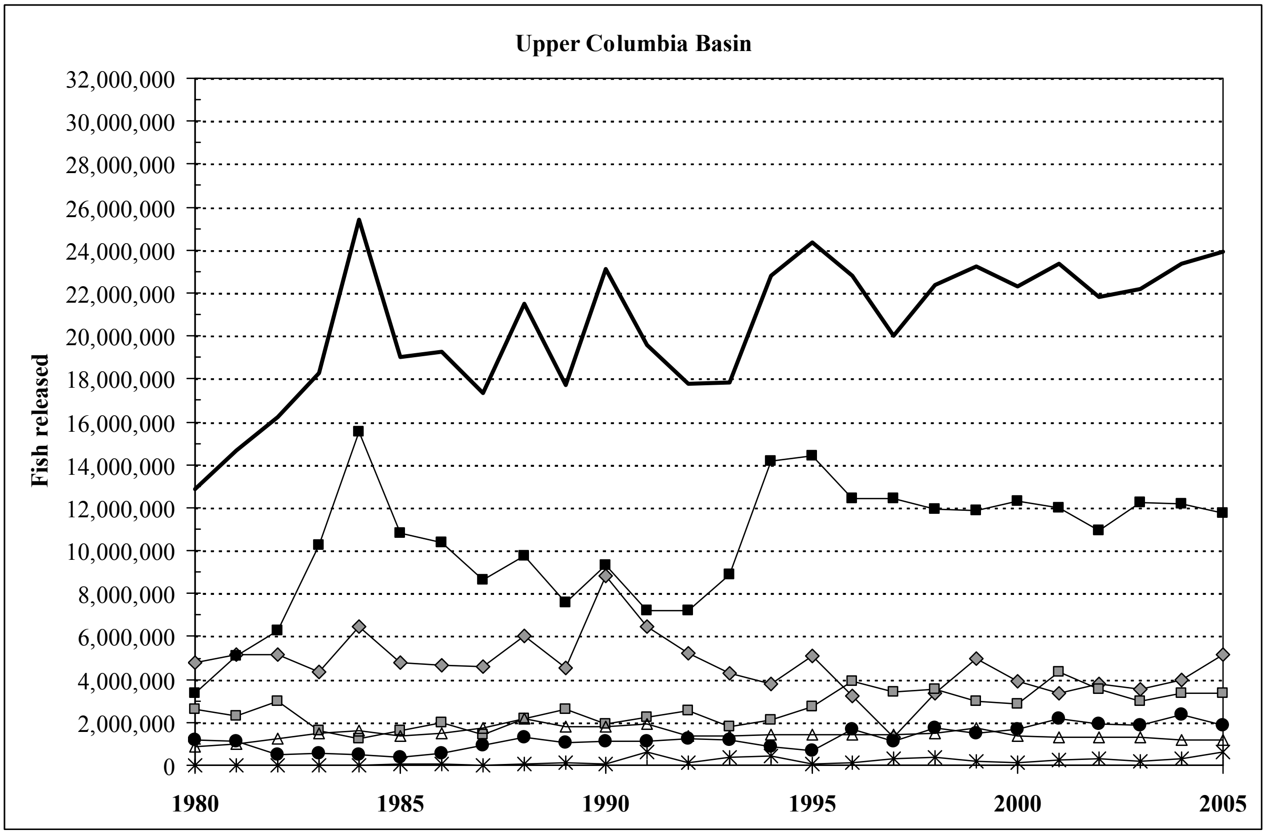


Figure 3. Releases of hatchery-reared juvenile salmon into the Lower Columbia Basin (below all mainstem dams) and into the Middle Columbia Basin between Bonneville Dam and the Columbia-Snake River confluence (above 1-4 dams), 1980-2005. Source: Fish Passage Center.



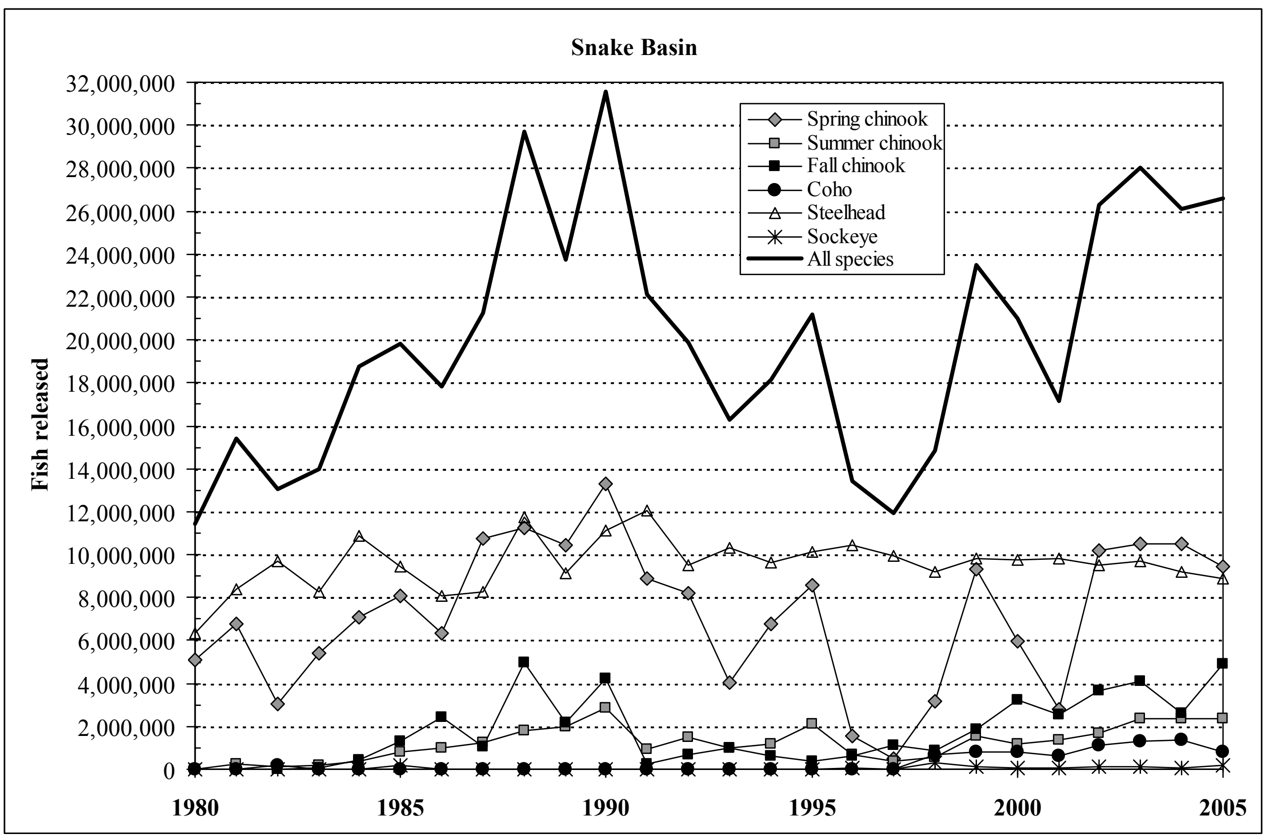


Figure 4. Releases of hatchery-reared juvenile salmon into the Upper Columbia Basin (above the Snake River and a total of 4-9 mainstem dams) and into the Snake Basin (above 4-8 dams), 1980-2005. Source: Fish Passage Center.

Compensating for Hydrosystem Mortality by Using Hatcheries to Increase Through-Put

Fish managers have substantially increased their production and releases of hatchery salmon smolts in upper portions of the CRB during the last few decades, as noted earlier. In simple terms, this reflects an effort to return substantial numbers of adult salmon by, in part, overwhelming the elevated mortality rates in the Columbia River hydrosystem with numbers. The approach has not always produced the desired result (i.e., abundant adult salmon), but it has produced some adult salmon while adding large numbers of potential (though not proven limiting) competitors for juvenile wild salmon in many of the river system's migratory corridors and the Columbia River estuary. A look at estimates of recent trends in the relative abundance of hatchery and wild spring Chinook salmon in the mainstem Snake and upper Columbia rivers is reflective of this situation and informative (Figure 5). In both rivers, juvenile spring Chinook from hatcheries first began outnumbering juvenile wild salmon in the mid-1970s, and now account for about 90% of the outmigrants. The basic through-put approach to solving problems posed by the hydrosystem requires the unnaturally high egg-to-smolt survival rates of fish bred in hatcheries and is not available to runs of wild salmon unsupported by hatcheries.

Spatial Patterns in the Relative Intensities[1] of Hatchery Releases

The numbers and species of salmon released from hatcheries vary among the differing subbasins of the CRB, reflecting the historic distributions of runs, mitigation patterns, and fish management strategies implemented by managers. Hatchery releases of all species of salmon (combined) have recently been most intense within subbasins containing, or immediately adjacent to, the Columbia River from approximately the Klickitat River to the estuary (six of the seven highest intensity subbasins), in or adjacent to Hells Canyon, in the Middle Fork of the Clearwater, and in the Upper Columbia-Priest Rapids and Wenatchee subbasins (Figure 6). The last two subbasins stand out because they also support several of the CRB's stronger salmon runs – Hanford Reach fall Chinook, Lake Wenatchee sockeye, and Wenatchee River summer Chinook. There are also a number of subbasins that stand out because they do not experience releases of hatchery salmon. These include a cluster of subbasins that constitutes the entire John Day River system within the Mid-Columbia Basin, and a cluster of subbasins that includes a large portion of Idaho's designated wilderness areas and undeveloped roadless country in the Snake Basin. These two clusters function as recognized reserves for wild salmon, with the John Day system containing

[1] In this context, the term "intensity" refers to the density (number of fish released per unit drainage area) of fish releases by hatchery programs active within a particular river system or geographic area. All Figures within this report that give maps depicting spatial patterns in the intensity of hatchery releases provide ranks (1, 2, 3,…) for the subbasins with the highest intensities.

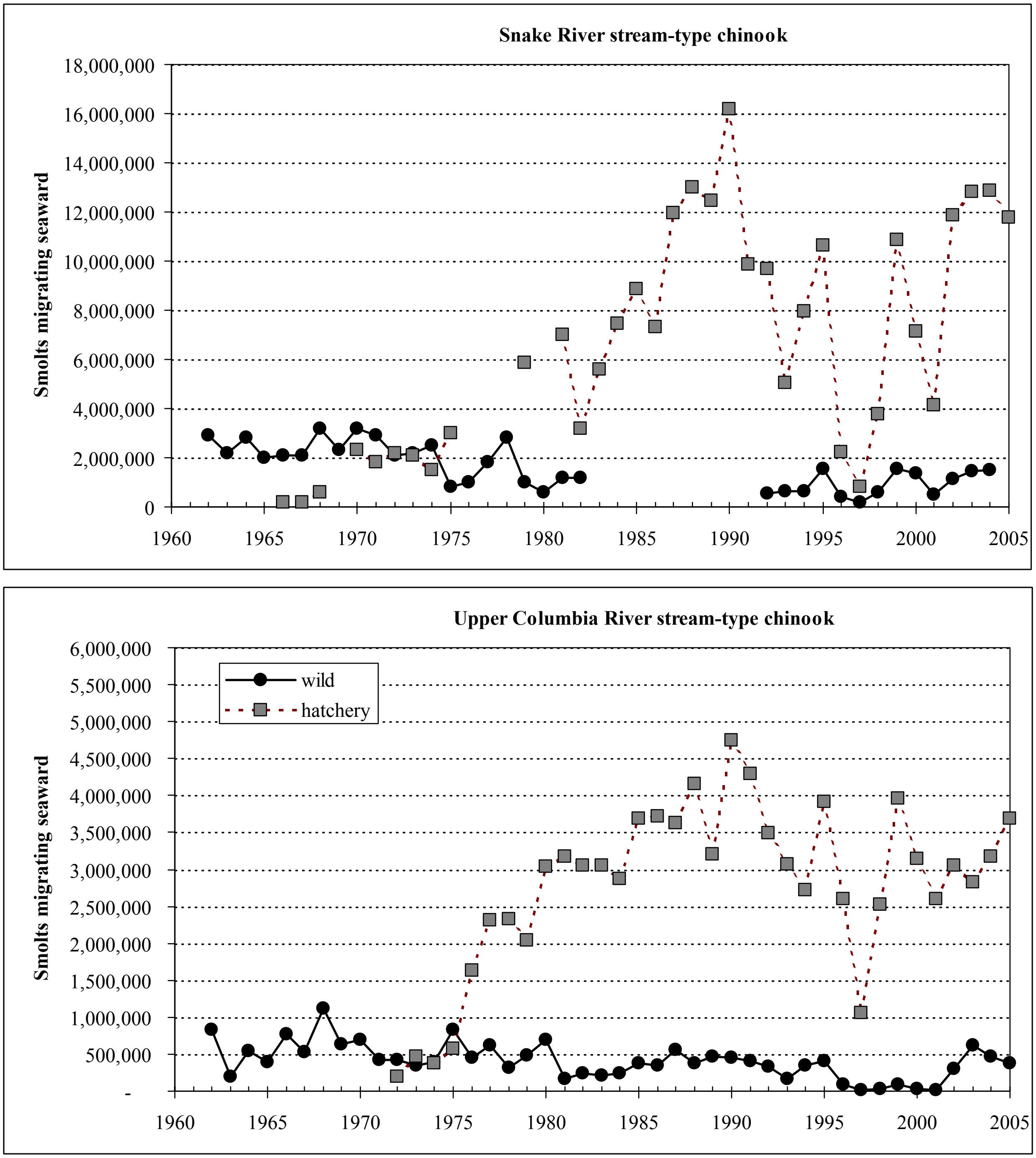


Figure 5. Estimated numbers of wild and hatchery-origin stream-type chinook salmon smolts migrating seaward from the Snake River Basin (top) and Upper Columbia River Basin (bottom), 1962-2005. Sources of information on Snake River fish were Raymond (1979), Petrosky et al. (2001), Copeland et al. (2005), and the Fish Passage Center. Sources of information for Upper Columbia River fish were Raymond (1988) and data needed to extend his 1962-1984 time series that were obtained from StreamNet (annual redd counts) and the Fish Passage Center (annual releases of hatchery smolts). Wild smolt numbers for the Upper Columbia during 2003-2004 were adjusted to reflect density compensation following large 2001-2002 adult escapements of supplementation fish.

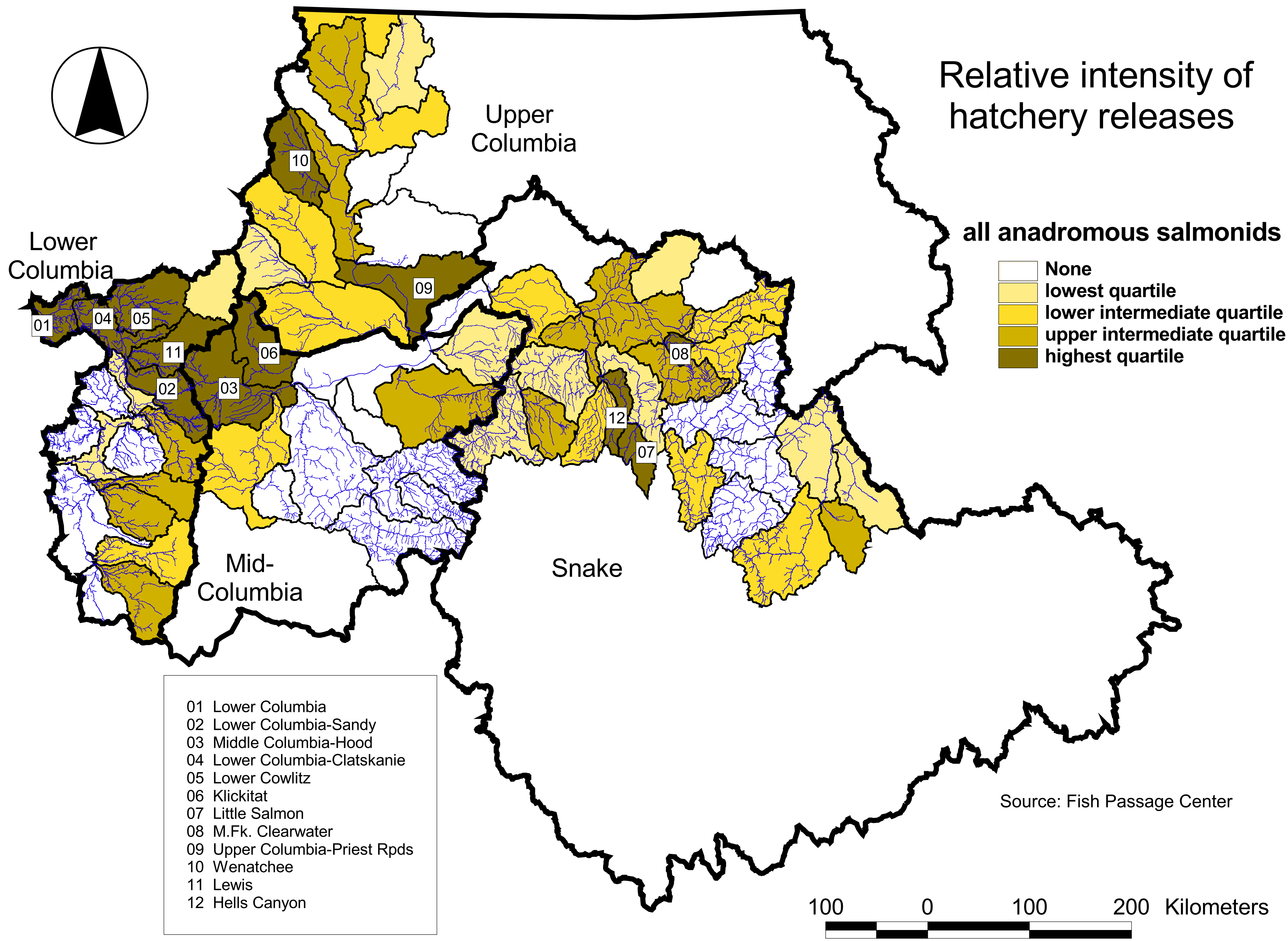


Figure 6. Spatial patterns in the relative intensity of hatchery releases of juvenile anadromous salmonids (# fish/drainage area) within the CRB, 2001-2005.

fragmented patches of high-quality habitat and the subbasins in Idaho being predominantly pristine.

Yearling Chinook. CRB hatcheries release yearling Chinook smolts, primarily spring-run fish but in some cases fish from summer or fall-run races, into 41 subbasins (Figure 7). During the last five years, these releases have been of the highest aggregate intensity within three subbasins in the Lower Columbia Basin (Lower Columbia, Middle Fork Willamette, and Lewis), in the Middle Columbia – Hood subbasin, in the Wenatchee subbasin, and in five subbasins within the Snake Basin (Little Salmon, Middle Fork Clearwater, South Fork Clearwater, Pahsimeroi, and South Fork Salmon). The highest intensity of release is found in the Little Salmon subbasin. The high aggregate intensity of releases in the Wenatchee subbasin is attributable to multiple spring Chinook programs and to summer (ocean-type) Chinook that are released as year-old fish into the Wenatchee River.

Subyearling Chinook. Hatcheries release subyearling Chinook (predominantly fall-run fish, but spring or summer runs at some locations) into 33 CRB subbasins (Figure 8). Those with the highest intensities of release during the last five years have included multiple subbasins containing, or immediately adjacent to, the Columbia River from approximately the Klickitat River to the estuary (six of the seven highest intensity subbasins), the Upper Columbia-Priest Rapids subbasin, and two subbasins containing the Snake River from Hells Canyon Dam downstream to the Clearwater River confluence (Hells Canyon and Lower Snake-Asotin).

Coho salmon. Juvenile coho are being released into 17 CRB subbasins at present, with highest-intensity releases clustered along the lower Columbia River (Figure 9). Subbasins with the highest intensity releases during the last five years have been the Lower Columbia, Lower Cowlitz, Klickitat, Lower Columbia – Sandy, and Lower Columbia – Clatskanie. Hatchery releases of coho into more than 10 subbasins in the Mid-Columbia Basin, Upper Columbia Basin, and Snake Basin represent recent tribal efforts to reintroduce the species to areas from which it was extirpated. Of these tribal efforts, releases into the Wenatchee subbasin in the Upper Columbia ranked in the second quartile for intensity among the subbasins into which coho were planted during the last five years.

Sockeye salmon. Sockeye are generally associated with lakes and the historic distribution of their rearing areas within the CRB was more restricted than that of most other types of salmon. Most of the lakes in which sockeye reared within the CRB prior to development have been blocked by dams. Today, hatchery programs release sockeye into three subbasins in the CRB (Figure 10), two in the Upper Columbia Basin (Wenatchee and Okanogan) and one in the Snake

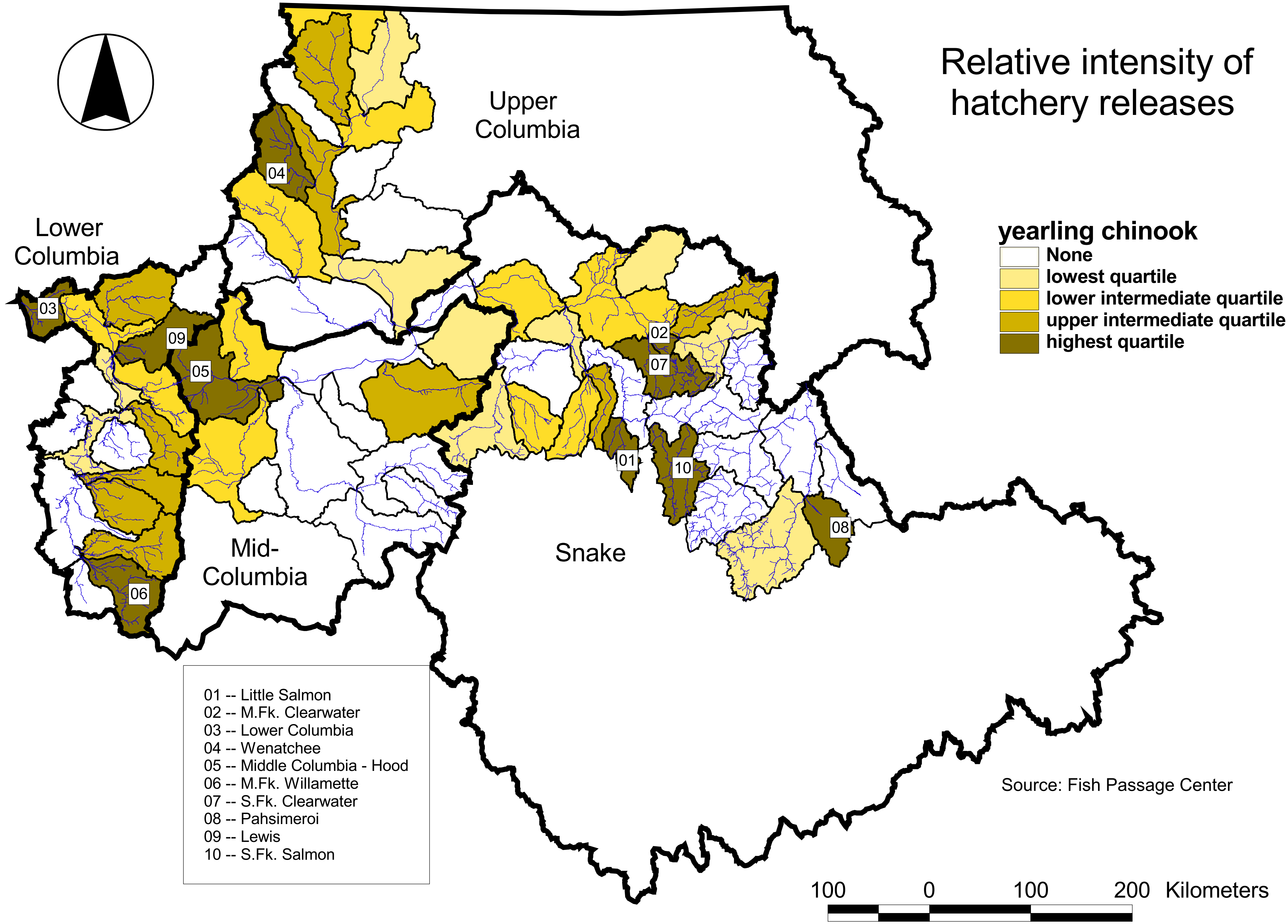


Figure 7. Spatial patterns in the relative intensity of hatchery releases of yearling chinook salmon (# fish/drainage area) within the CRB, 2001-2005.

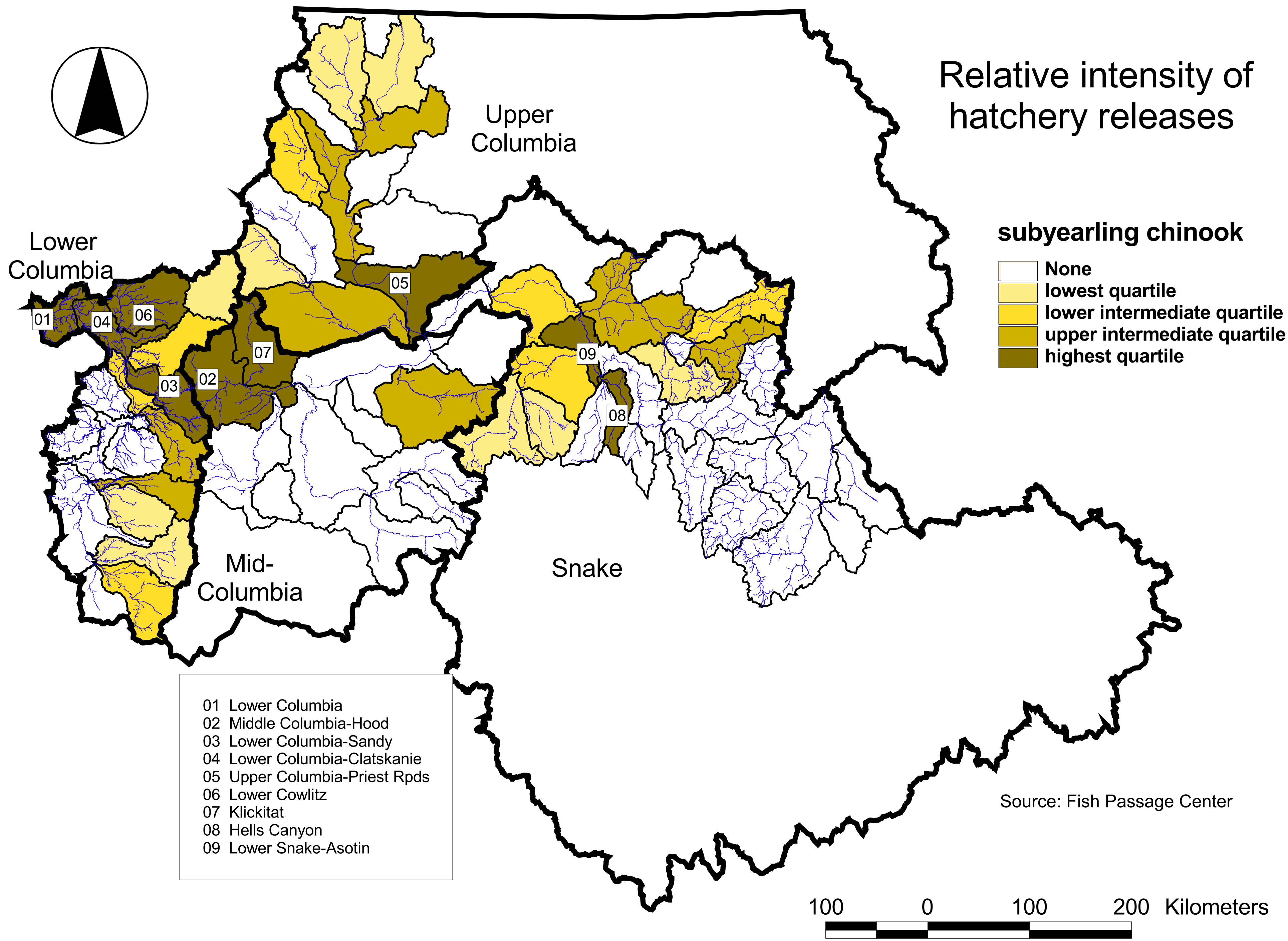


Figure 8. Spatial patterns in the relative intensity of hatchery releases of subyearling chinook salmon (# fish/drainage area) within the CRB, 2001-2005.

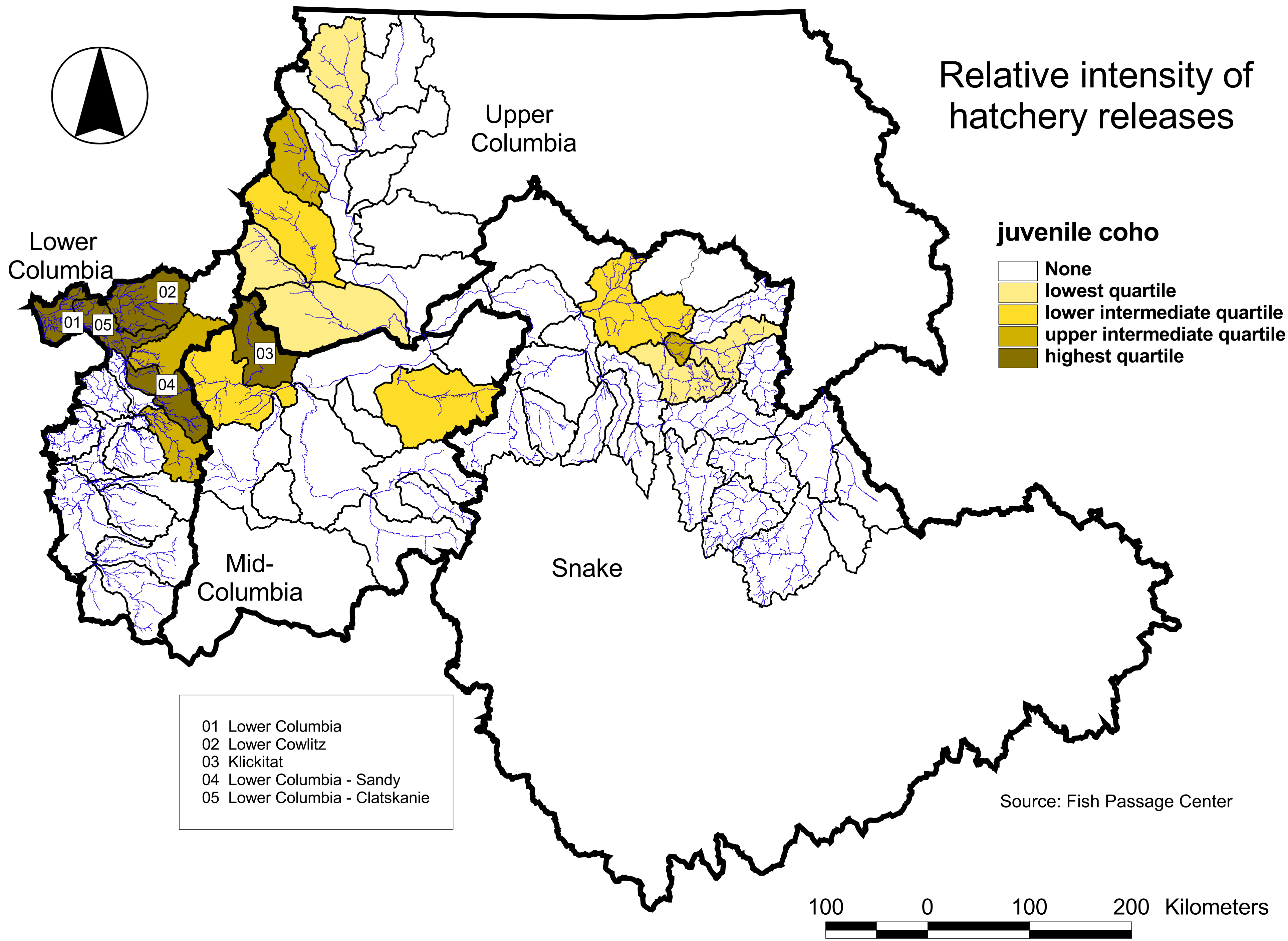


Figure 9. Spatial patterns in the relative intensity of hatchery releases of juvenile coho salmon (# fish/drainage area) within the CRB, 2001-2005.

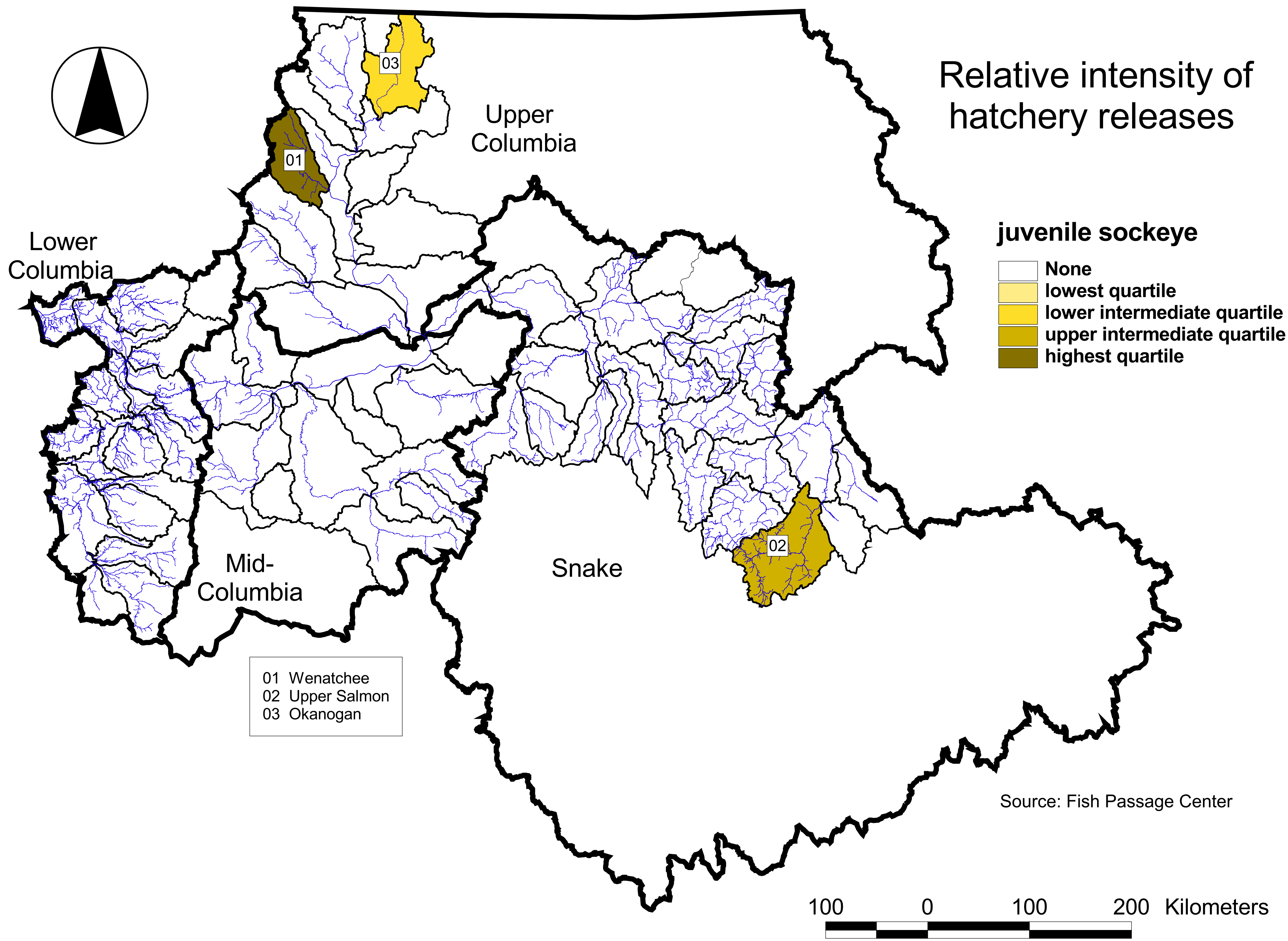


Figure 10. Spatial patterns in the relative intensity of hatchery releases of juvenile sockeye salmon (# fish/drainage area) within the UCB, 2001-2005.

Basin (Upper Salmon). Of the three subbasins, the Wenatchee receives the largest annual releases of hatchery fish (200,000), but a captive-brood program for Redfish Lake sockeye in Idaho's Upper Salmon subbasin is generally better known.

Steelhead trout. Hatcheries have released juvenile steelhead into 37 CRB subbasins during the last five years, with the releases of greatest intensity occurring in specific portions of the Snake and Lower Columbia basins (Figure 11). During this time the releases of highest intensity have occurred in eight subbasins tributary to or along the Snake River (Little Salmon, Middle Fork Clearwater, South Fork Clearwater, Pahsimeroi, Wallowa, Upper Salmon, Hells Canyon, and Clearwater) and in two subbasins tributary to the lower Columbia River (Lower Cowlitz and Lewis). Hatchery releases into the Wenatchee and Methow subbasins in the Upper Columbia ranked in the second quartile for intensity among the subbasins into which steelhead were planted during the last five years.

TYPES OF HATCHERY PROGRAMS

From a conceptual standpoint, there are three basic types of hatchery programs producing salmon in the CRB and elsewhere, two of which have been described in detail by the HSRG (2004). One, the conventional ***segregated hatchery***, is properly managed when it keeps its hatchery-produced fish away from wild ones of the same species when they return to spawn, with the percentage of hatchery-origin spawners (pHOS) reaching natural spawning areas kept below 5% as a maximum (Figure 12). Fish in these programs breed with one another for multiple consecutive generations in the hatchery and accumulate characteristics favorable for a salmon lifecycle that includes hatchery rearing but unfavorable for completing a full life in the wild. They should be kept away from the spawning areas of wild salmon in order to constrain reductions in the fitness of wild populations that occur when they interbreed. Straying of hatchery fish from segregated programs to the spawning areas of wild fish can be minimized by siting hatcheries away from spawning grounds, maximizing the homing of returning adult hatchery fish to the hatchery, removing hatchery fish of this type from mixed runs of adults using selective fisheries or sorting facilities, and/or reducing the numbers of hatchery fish released.

Segregated hatchery programs have operated for a long time in the CRB, though often without significant controls on the degree to which the salmon they produced strayed to natural spawning areas. Natural spawning by fish from these programs has been, and continues to be, a risk factor for wild populations unless it is very tightly controlled (NRC 1996; ISG 2000; HSRG 2004).

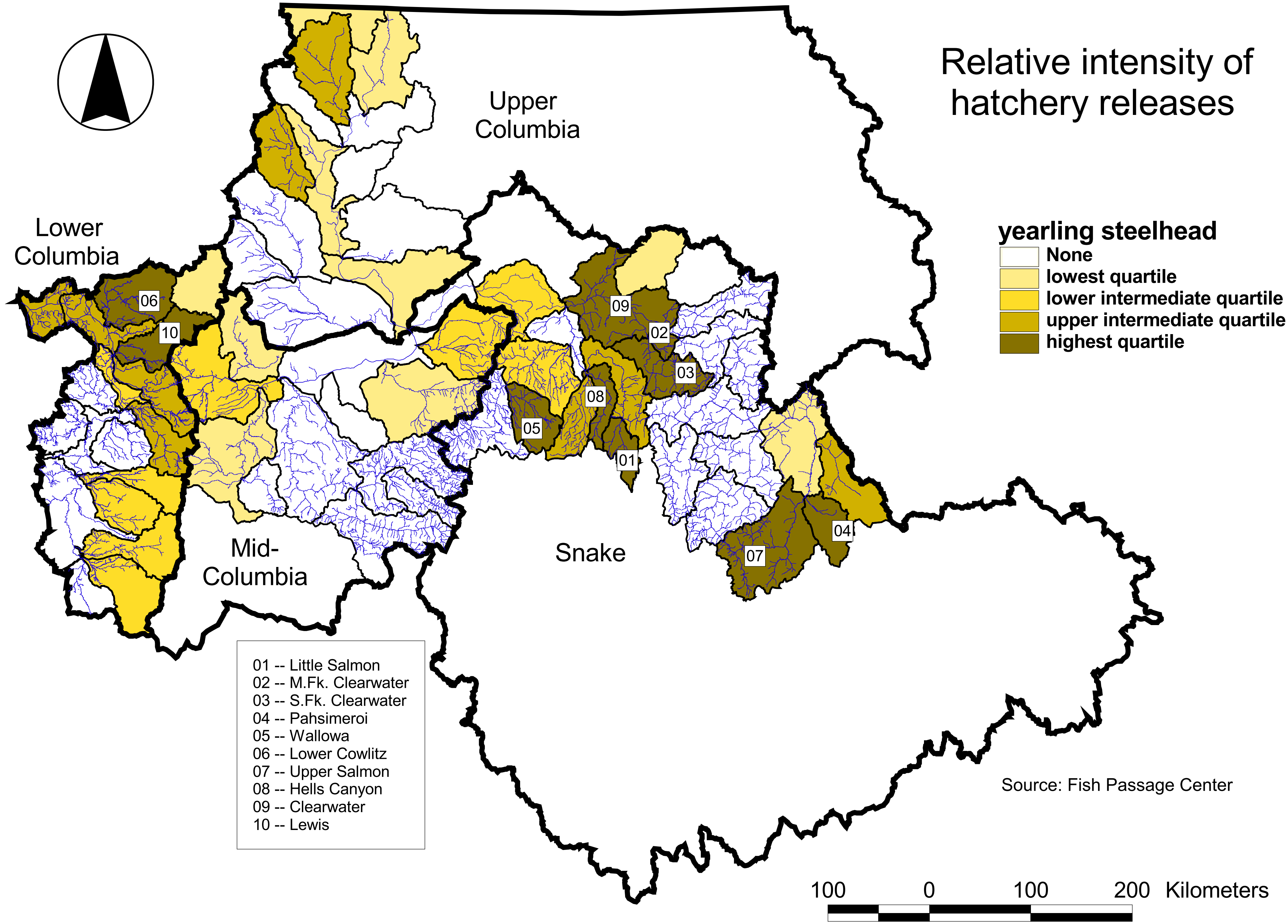


Figure 11. Spatial patterns in the relative intensity of hatchery releases of yearling steelhead (# fish/drainage area) within the CRB, 2001-2005.

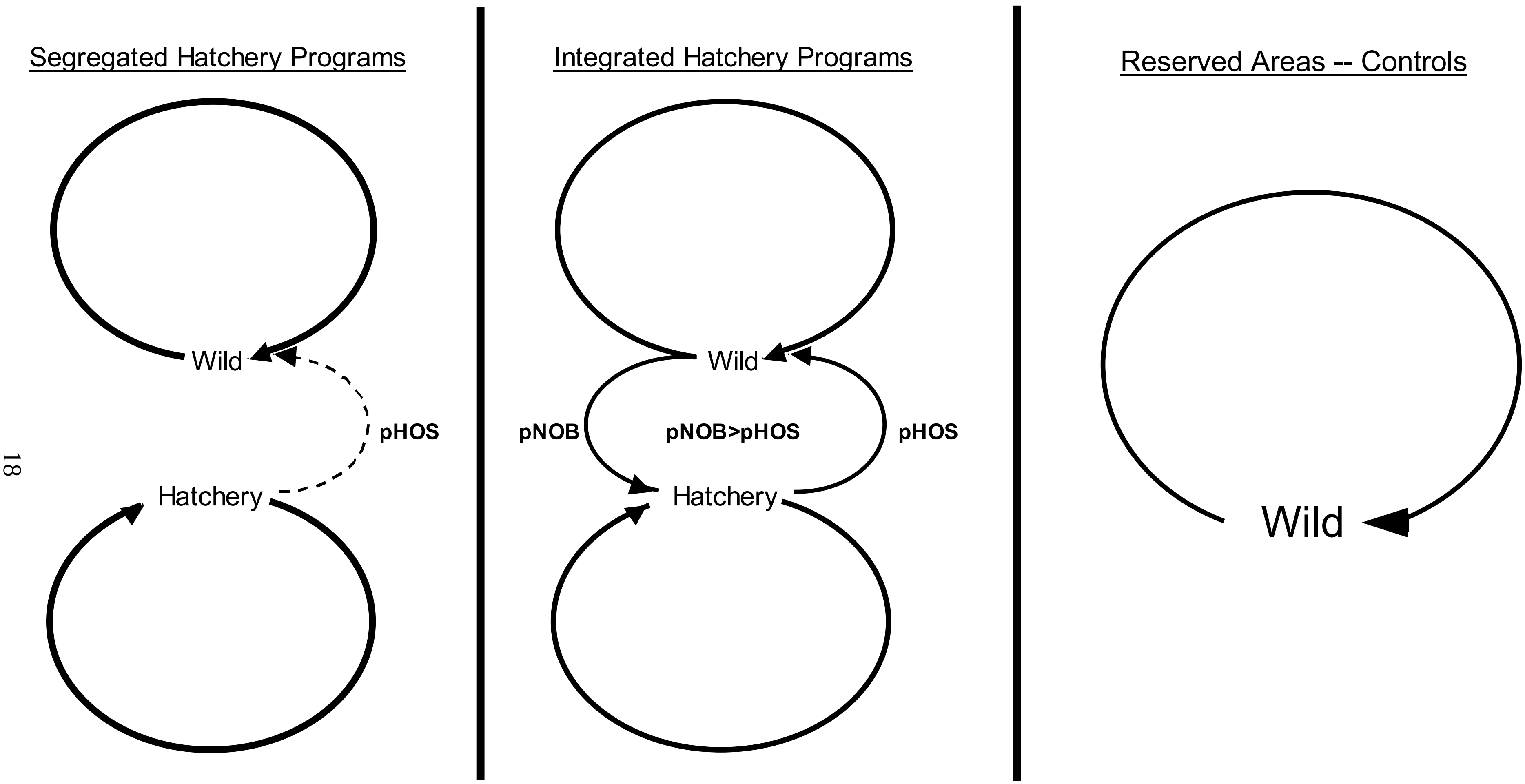


Figure 12. Basic types of hatchery programs. When managed according to “best management practices” (BMPs) defined by the Hatchery Science Review Group (HSRG 2004), “segregated programs” have less than 5 percent hatchery-origin spawners (pHOS) in natural spawning areas. For “integrated programs”, the HSRG recommends a higher percentage of natural-origin fish in the hatchery broodstock (pNOB) than the percentage of hatchery-origin spawners (pHOS) in natural spawning areas, and a substantially higher percentage where the stock incorporated into the hatchery program is of high conservation value. Reserved areas are important as wild fish refuges and as controls on hatchery experiments.

A second type of hatchery program, which though experimental is now being widely applied in portions of the CRB, intentionally integrates hatchery and wild production of salmon within a watershed (Figure 12) by using controlled numbers of wild fish in its broodstock and supplementing natural spawning populations with controlled numbers of hatchery-origin adult fish. In an idealized form (small, temporary hatcheries emphasizing conservation), these ***integrated hatchery*** programs would fit the vision of landscape-based hatcheries proposed by Williams et al. (2003). However, multiple assessments have raised concerns about them as they are actually applied and suggested that they be used sparingly due to concerns about their potential to cause cumulative erosion in the natural fitness (productivity) of the salmon population involved (e.g., NRC 1996; ISAB 2003; Meyers et al. 2004; ISRP 2005).

The goal of most integrated hatchery programs is to be more conservation-minded, work in harmony with watershed restoration efforts, help dwindling runs of salmon, and in many cases to help support harvest in fisheries (HSRG 2004). As conceived, they are intended to boost the natural production of salmon while limiting accumulations of unfavorable genetic changes that will reduce the natural fitness of those wild salmon populations incorporated into the programs. The available science suggests that keys to the conservation efficacy of these programs is likely to be whether the habitat available to the salmon population involved has substantial unused carrying capacity (e.g., Nickelson et al. 1986); the ability of managers to account for variations in the availability of this unused capacity (Oosterhout et al. 2005); the degree to which the programs use wild broodstock (Ford 2002; HSRG 2004; Araki et al. 2006); the degree to which innovative rearing techniques used in the hatchery yield juvenile salmon little-changed from those in the wild (Flagg et al. 2000; Williams et al. 2003) or that this is possible (Kostow 2004); the ability to control the numbers of hatchery-origin adults in spawning areas (HSRG 2004), and the duration of operations (Lynch and O'Hely 2001; Ford 2002; Goodman 2005; shorter would be better).

Taken as a whole, many of the integrated hatchery programs being recommended as an element of hatchery reform (HSRG 2004) are being designed to limit, not necessarily prevent, losses of natural fitness in salmon populations. Where applied to declining salmon populations in the CRB, integrated programs thus have the potential to impede the long-term ability to restore the affected populations to self-sustaining status (i.e., without continued hatchery support) if at some time in the not too distant future the factors currently placing the populations at risk, including multiple aspects of the CRB hydrosystem, are remedied. Application of these types of programs, therefore, would seem to signal a need to speed efforts to address the factors for population decline if society's long-term goal is to restore self-sustaining salmon populations.

The third basic hatchery program "type" is the ***reserve*** where wild salmon are un- or little affected within their home watershed by hatchery-origin fish. Such areas should serve as relative strongholds for wild salmon (Rahr et al. 1998) and as controls on broad-scale conservation experiments being conducted with integrated fish hatcheries (NRC 1996; ISAB 2003; ISRP 2005).

A recent self-assessment of fish hatchery programs in the CRB identified 68 hatchery stocks of salmon in the basin that were managed to be segregated from natural populations, 105 stocks that were integrated hatchery-wild composites, and 88 natural (wild) stocks intended to have limited hatchery influence (APRE 2004). The review also found that control of the numbers of hatchery-origin fish in natural spawning areas was less effective than desired for many of the basin's segregated and integrated programs.

CONCERNS ABOUT NATURAL SPAWNING BY HATCHERY-ORIGIN SALMON

The proper management of hatchery-origin salmon is of concern to those attempting to reverse salmon declines because the consequences of improperly mixing the two in nature can be unfavorable for wild salmon. One of the greatest concerns is that salmon whose lineage reflects repeated consecutive breeding cycles by hatchery-origin adults can be far less fit for completing a full salmon life-cycle in nature than are wild fish. This difference in natural fitness between the two types of salmon reflects accumulated adaptations to their differing environmental experiences (HSRG 2004). A recent meta-analysis of the available research by the Salmon Recovery Science Review Panel (RSRP 2004) has suggested that the loss of natural fitness caused by rearing in a conventional segregated hatchery environment may be as high as 20% per generation in multi-generational lines of hatchery fish. Another concern, sometimes overlooked but important, is that density-dependent interactions (i.e., competition) between the offspring of hatchery-origin and wild spawners can reduce the survival rates of the wild fish if streams are supporting juvenile fish at levels near or at carrying capacity. Even in cases where the hatchery-origin fish have reduced natural fitness, such density-dependent effects could contribute to reductions in the abundance of wild fish (e.g., Nickelson et al. 1986).

The latest authoritative study relevant to the hatchery-wild salmon issue, a genetic-pedigree analysis of the contributions of wild and supplemented hatchery-origin steelhead to subsequent generations of fish in the Hood River, Oregon, was consistent with a review of the science by Berejikian and Ford (2004), confirming that multi-generational lines of hatchery fish had substantially lowered fitness in the wild (Araki et al. 2006). It also suggested that the fitness reduction caused by passing wild-origin fish through one breeding and rearing cycle in the hatchery and returning them to nature to provide a boost in abundance to their wild population was at most small unless the fish that experienced the hatchery rearing cycle bred with each other on the spawning grounds. Araki et al.'s results offer support for the concept of tightly managed conservation hatcheries that might operate for short periods of time, but offer a cautionary reminder of the risks that may be posed by integrated hatchery programs that do not limit the cycling of hatchery-origin broodlines or that do not keep the number of their hatchery-origin adults on the spawning grounds small enough to preclude extensive natural breeding between pairs of hatchery-origin fish.

Potential reductions in natural fitness caused by hatcheries are of critical concern in ongoing regional efforts to recover at-risk populations of salmon. Fitness reductions in salmon populations caused by improperly managed hatchery programs, whether the programs are "segregated" or "integrated", are likely to be expressed in nature as reductions in the life-cycle survival rates of the affected natural salmon populations. As such, poorly managed programs have the potential to work against survival gains that might otherwise be achieved in the CRB by reducing hydrosystem mortality, improving habitat quality, or further reducing salmon harvest rates (ICBTRT 2005). As suggested earlier, these types of gains are critical to the recovery of the CRB's ESA-listed salmon populations (NMFS 2000; ICBTRT 2006).

The reversibility of hatchery-related reductions in the natural fitness of salmon has not been studied, but a full recovery of fitness in an affected natural population seems unlikely to occur immediately upon removing the active influence of a hatchery program (ISRP 2005). The more slowly the reversal in fitness actually occurs, the more substantial the long-term consequences of the fitness reductions in the natural population. Regardless, for at least some at-risk CRB salmon populations, it has apparently been judged necessary to accept the risk of reductions in natural fitness that may be caused by tightly managed integrated hatchery programs provided that there are serious efforts to remedy the factors threatening the populations (including problems posed by CRB hydrosystem mortality). There are, unfortunately, no examples in the CRB of which I am aware that show a hatchery program played a role in transforming a declining salmon population into a self-sustaining one.

CONDITIONS IN THE COLUMBIA CASCADE PROVINCE

The following section of the report provides an overview of the state of the natural salmon populations and of the hatchery programs associated with them, in the Columbia Cascade Province. It emphasizes the species that might somehow be involved in programmatic changes affecting the USFWS's Leavenworth National Fish Hatchery Complex (the "Leavenworth Complex"), and also includes limited discussions of fisheries associated with them because of interest in these fisheries expressed by Trout Unlimited staff.

The Province and the Leavenworth Complex

The Columbia Cascade Province constitutes the majority of the Upper Columbia Basin that remains accessible to anadromous fish, including an extended segment of the mainstem Columbia River as well as the Wenatchee, Entiat, Methow, and Okanogan subbasins, plus multiple smaller watersheds tributary to the mainstem (Figure 13). The Province is the geographic and ecological setting of the Leavenworth Complex, a set of three large, conventional fish hatcheries operated by the U.S. Fish and Wildlife Service: Leavenworth, Entiat, and Winthrop. All three hatcheries are located on streams draining the eastern slopes of the Cascades in Washington. Leavenworth National Fish Hatchery (NFH) is located on lower Icicle Creek, a tributary to the Wenatchee River 26 miles above the river's mouth. Entiat NFH is situated near River Mile 6 on the Entiat River. Winthrop NFH is positioned along the Methow River near River Mile 45 and just upstream of the Chewuch River confluence.

Construction and operation of the Leavenworth Complex was initially authorized on 30 August 1935 under the Grand Coulee Dam Project, 49 Statute 1028, as part of the Rivers and Harbors Act. It was then reauthorized on 10 March 1943 under the Columbia Basin Project Act, 57 Statute 14, and subsequently under the Fish and Wildlife Coordination Act, 60 Statute 1080, on 14 August 1946. The Complex operates under guidance suggesting that it maintain salmon runs as mitigation for fish losses associated with the construction of Grand Coulee Dam. This guidance places an emphasis on providing harvest to compensate for production lost from 1,140 miles of blocked salmon habitat.

Fish managers struggled in the late 1930s and early 1940s to salvage salmon runs blocked by the construction of Grand Coulee Dam, on the Columbia River at River Mile 596, 51 miles upstream of the current site of Chief Joseph Dam. This effort, which was the basis for initial construction of the Complex, dramatically altered the natural genetic relationships among salmon populations in the Columbia Cascade Province. Adult salmon returning to the drainage basin above the site of Grand Coulee Dam, as well as to much of the Columbia Cascade Province itself, were

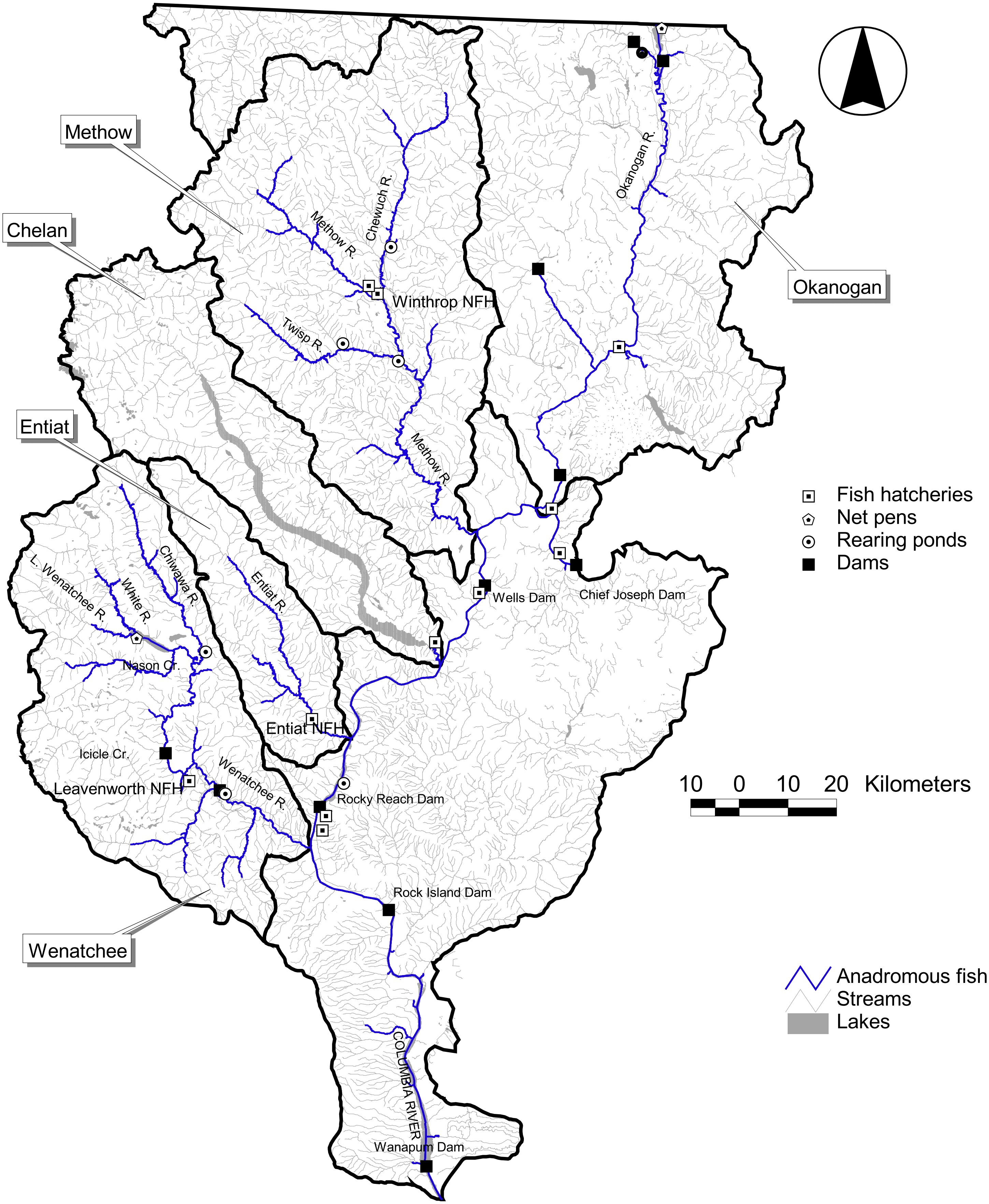


Figure 13. The Columbia Cascade Province, its subbasins, and artificial production facilities for anadromous fish.

collected at Rock Island Dam and redistributed to Leavenworth Complex facilities and the larger drainage basins within the Province. Subsequent to the salvage operation, there is evidence that there has been some geographic population restructuring for Chinook salmon, but not for steelhead (e.g., Ford et al. 2001). The restructuring that has occurred would be expected to be adaptive and to enhance the productivity of existing salmon runs.

Spring Chinook salmon

Estimated annual runs of wild spring Chinook passing over Priest Rapids Dam toward spawning areas in the Columbia Cascade Province have averaged 2,178 fish (range = 173 – 8047) during the 10-year period ending in 2005 (ODFW & WDFW 2006). These fish have generally not been replacing themselves from one generation to the next (UCSRB 2006) and were listed under the ESA as Endangered in March 1999. Annual harvests rates on them in downriver fisheries have averaged 9.8% (range = 4.8-14.8%) in the years since the listing (2000-2005; ODFW & WDFW 2006).

Severe declines and low abundance of wild spring chinook populations in the Columbia Cascade Province, plus a lack of hydrosystem survival improvements sufficient to provide confidence that the declines would be reversed, led state fish managers (WDFW) in the late 1980s and early 1990s to initiate multiple experimental, integrated hatchery programs to conserve these fish. The programs appear to have slowed near-term fish declines in targeted salmon populations but also experienced unintended consequences because of their relatively large size, imperfect adult collection facilities, and small geographic distances between target and non-target salmon streams. Stray spawners from WDFW's integrated programs, and from the large federal hatcheries within the Leavenworth Complex, are causing higher than desired proportions of hatchery-origin fish in multiple spawning areas. For example, Cooper et al. (2006) estimated that adult spring Chinook from Leavenworth NFH's "segregated" hatchery program accounted for about 35% of the naturally spawning fish in the Wenatchee subbasin upstream of Icicle Creek during 2001-2003, a period of high returns of hatchery-origin fish. The stray rate in this example was only 2.6%, but the large size of the hatchery population relative to the meager wild runs returning to most of the upper Wenatchee subbasin accounted for the very large exceedance of recommended limits for the presence of hatchery fish from segregated programs in natural spawning areas (pHOS<5%; HSRG 2005). In another example, within the Methow subbasin, hatchery-origin adults from the integrated hatchery program for spring Chinook have greatly outnumbered naturally produced adults in multiple spawning areas since the program began returning significant numbers of fish in 2000 (see Appendix B). The effect of these uncontrolled hatchery-origin spawners on natural population productivity has likely been negative.

An ongoing review of the Leavenworth Complex may change its spring Chinook programs to reduce potential problems caused by straying of hatchery-origin fish. There has been no commitment as to when or if the experimental integrated hatchery programs for spring chinook in the Province will end, although any negative effects they have on the ability of the populations to sustain themselves without hatchery support would be expected to accumulate through time. Agreements intended to mitigate salmon losses due to the hydrosystem suggest that the programs will not end and some may be expanded.

Wenatchee Subbasin. Runs of naturally produced spring Chinook returning to the Wenatchee River, above 5 hydroelectric dams in 1960 and above 7 dams since 1968, have dropped dramatically over the last 45 years despite fishery reductions and closures intended to help conserve them (Figure 14). Hatchery production of spring Chinook has increased within the subbasin over this period of time, and since 1989 has included a large segregated hatchery program at the Leavenworth NFH and integrated hatchery programs of varying size. During the last five years, data available from the Fish Passage Center indicate that Leavenworth NFH has produced an average of 84% (range = 67-97%) of the annual number of artificially produced spring Chinook smolts released into the subbasin.

Escapements of spring Chinook to spawning areas in the Wenatchee subbasin last reached the ESA viability threshold of 2,000 naturally produced adults (ICBTRT 2005) in 1986. However, total escapements to natural spawning areas, including hatchery-origin fish exhibited a pronounced upturn recently in response to a period of improved downstream migration and ocean survival conditions, as well as to increased returns from an integrated hatchery program on the Chiwawa River. Recent escapements of adults from the Chiwawa's hatchery program to their home watershed and others, and of stray adults from the USFWS's Leavenworth NFH (which propagates a non-local Carson stock), have substantially elevated the hatchery-origin proportion of adults spawning in multiple areas of the subbasin.

The integrated hatchery program on the Chiwawa River, operated by the state, has expanded to the point that it is now producing large numbers of hatchery-reared smolts and returning significant numbers of hatchery-origin adults to spawning areas, including non-target areas along the upper mainstem Wenatchee River and adjacent Nason Creek (see Figure 13). The program appears to have helped give a near-term boost in abundance to the targeted component of the Wenatchee River spring Chinook population, but about 27% of its returning adults are straying to non-target spawning areas (WDFW 2005). The conservation benefit of a continuation of recent high annual levels of hatchery-origin smolt releases into the Chiwawa (e.g., 494,517 in 2006) is not clear, however, as these releases appear to be out of proportion to the stream's

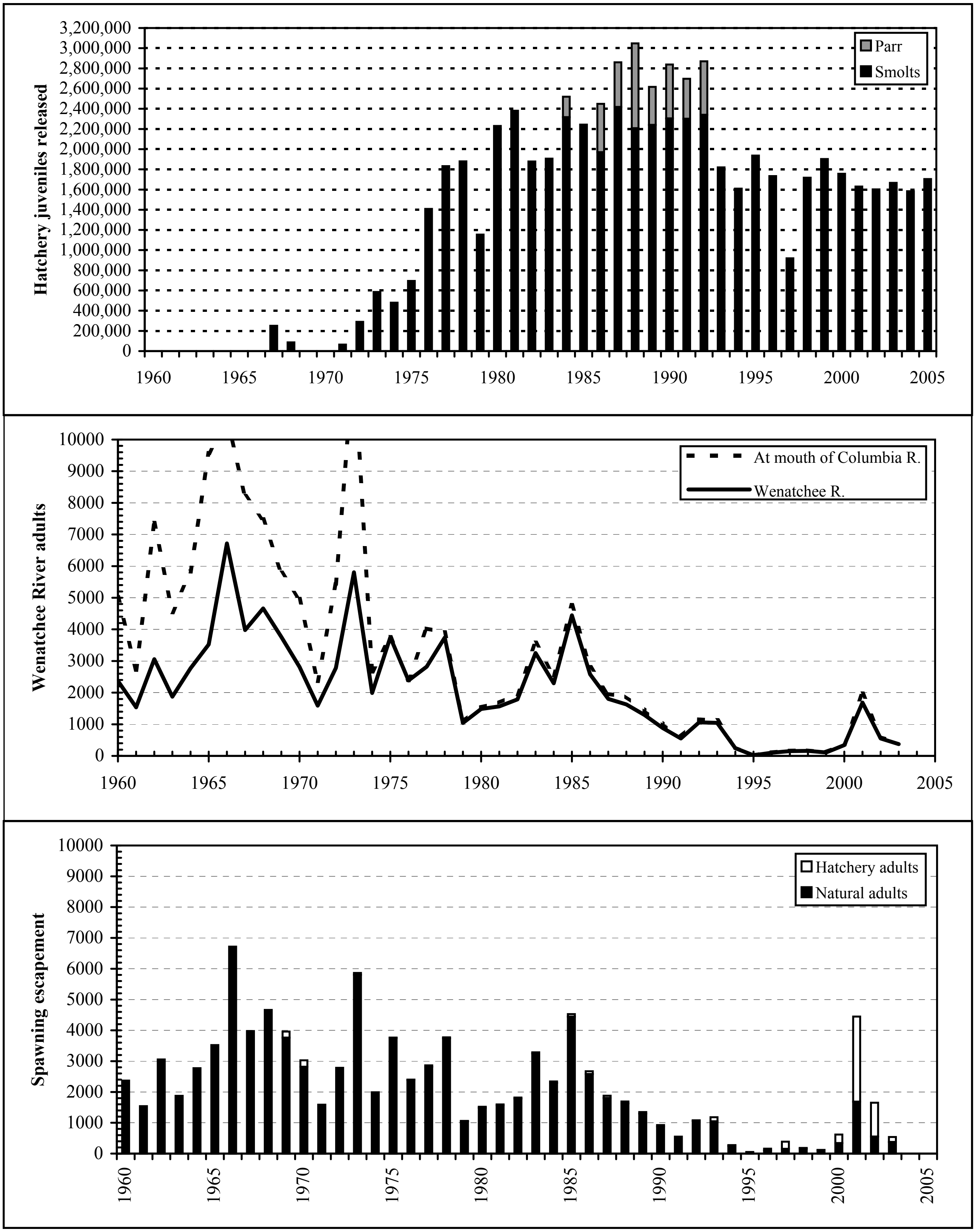


Figure 14. Hatchery releases, estimated returns of naturally produced adults, and estimated spawning escapements of hatchery and wild adults for spring chinook in the Wenatchee River, 1960-2005.

Sources: Chapman et al. (2005), Fish Passage Center, Good et al. (2005), and UCSRB (2006).

natural carrying capacity. Available data show a significant positive relationship ($p<0.05$) between index redd counts in the stream during a brood year and the number of hatchery reared smolts of that same brood released into the stream, a pattern that may exaggerate between-year variation in adult returns and make it more difficult to manage the program to avoid exceeding carrying capacity. The Chiwawa program is being well monitored, however, so adjustments will be possible and it should help inform future uses of hatchery programs of this type elsewhere.

A harvest framework drafted by WDFW (2006) but not yet authorized by NOAA Fisheries establishes an escapement objective of 4,100 ESA-listed spawners (wild and hatchery-origin combined) to ensure that the Wenatchee subbasin's carrying capacity for adult spawners is met when possible. According to the framework, ESA-listed spring Chinook adults of hatchery origin (marked fish) in excess of those needed to meet the escapement objective would first be used for release into Peshastin Creek, a lower Wenatchee River tributary that currently lacks a local-origin run of spring Chinook. If the number of ESA-listed adults reaching the Wenatchee River exceeded that needed to reach carrying capacity, including in Peshastin Creek, a selective recreational fishery would be allowed in the lower Wenatchee River. The selective fishery would target the "excess" ESA-listed hatchery fish and be constrained by a limit on the incidental take (mortality) of naturally produced (wild, unmarked) ESA-listed fish. The proposal does not make clear whether levels of hatchery production in the subbasin will be reduced during any extended periods in which annual escapements of ESA-listed spring Chinook consistently exceed the fishery thresholds, as a way to increase opportunities for expansion of the naturally produced components of integrated groups of hatchery-origin and wild spawners.

Entiat Subbasin. Runs of naturally produced Chinook salmon returning to the Entiat River, above 5 hydroelectric dams in 1960 and above 8 dams by 1968, have declined over the past 45 years despite fishery reductions and closures initiated to help offset a combination of hydrosystem mortality and an extended period of low ocean survival rates (Figure 15). Hatchery fish of non-local Carson stock produced in a segregated program at Entiat NFH during this period have strayed to natural spawning areas within the subbasin and interbred with the native run to the extent that the two are now difficult to distinguish through standard genetic analyses (Ford et al. 2004). Hatchery-origin adults strayed from Entiat NFH to natural spawning areas within the subbasin at an average rate of 7.9% from 2000-2005, contributing more than 31% of the spawners found in those areas (Cooper at al. 2006).

Spawning escapements of naturally produced spring Chinook in the Entiat system last reached the ESA-related viability threshold of 500 naturally produced adults (ICTRT 2005) back in 1978. Recent escapements of wild spring Chinook to natural spawning areas in the subbasin have risen

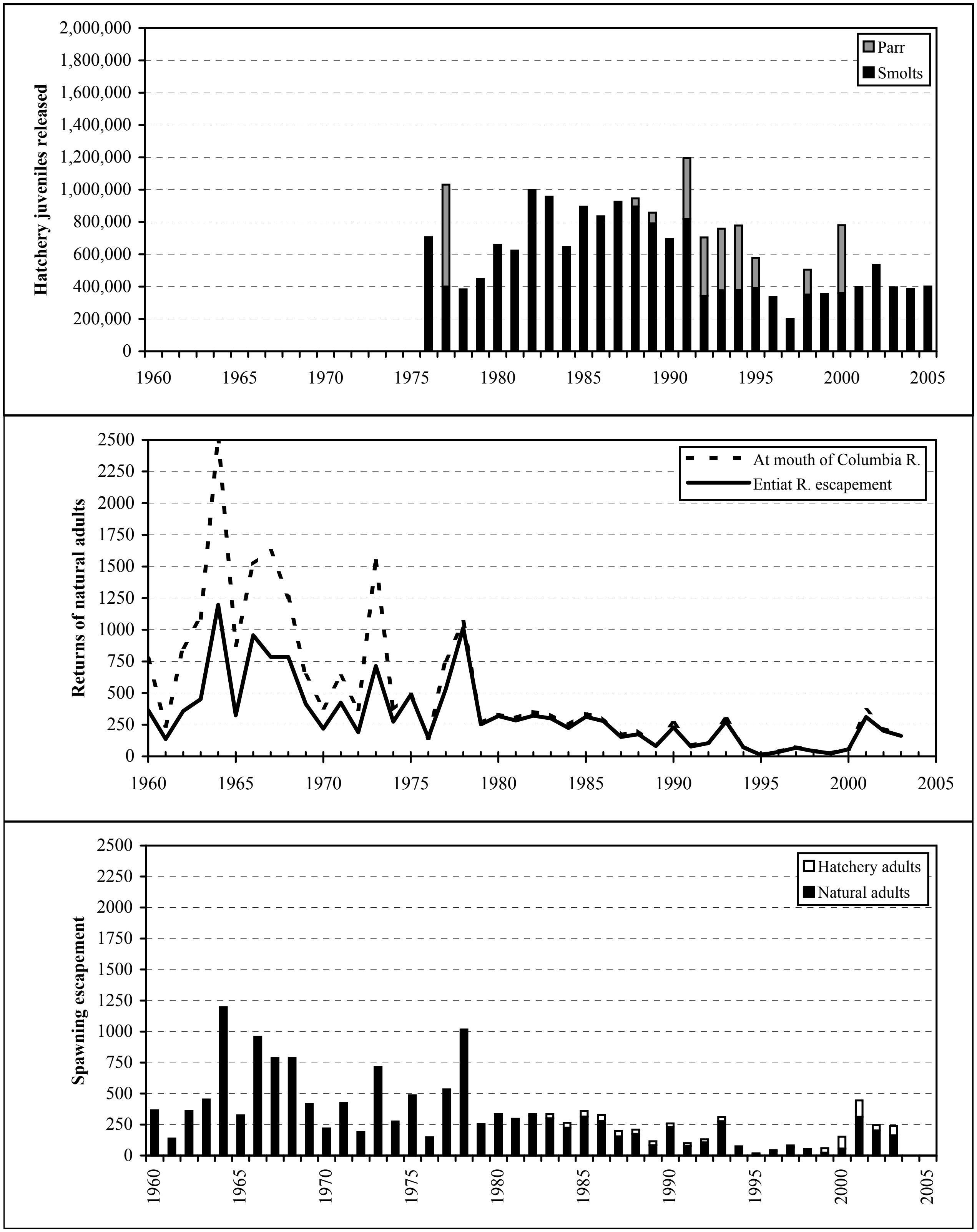


Figure 15. Hatchery releases, estimated returns of naturally produced adults, and estimated spawning escapements of hatchery and wild adults for spring chinook in the Entiat River, 1960-2005.

Sources: Chapman et al. (1995), Fish Passage Center, Good et al. (2005), and UCSRB (2006).

somewhat but remain low. Carson-stock hatchery fish that stray from the imperfectly segregated program at Entiat NFH when returning as adults continue to be common in the natural spawning areas.

The Carson stock spring Chinook reared and released from Entiat NFH are non-local, not listed under the ESA, and intended to augment fisheries. They have no clear conservation benefit. WDFW (2006) has proposed a "new" recreational fishery for these spring Chinook when their abundance in the Entiat exceeds 800 adults and the return of naturally produced Chinook to the system exceeds a minimum of 100 adults. The fishery would operate selectively in the lower Entiat River to harvest hatchery-origin fish while making increasing allowances of from 2 percent up to 10 percent incidental take (mortality) of the ESA-listed wild run returning to the river as that run's abundance approached and exceeded the viability threshold of 500 adults.

Methow Subbasin. Runs of naturally produced spring Chinook into the Methow subbasin, above 5 hydroelectric dams in 1960 and above 9 dams by 1968, had declined to the point that critically low returns in the mid- to late 1990s caused fish managers great concern about the ability to maintain even hatchery-influenced runs here (Figure 16). In response, most or all of the adult spring Chinook returning to the river in those years were captured downstream at the only fully effective collection point available, Wells Dam on the Columbia River, and their offspring reared at Methow SFH and Winthrop NFH. The collection effort downstream was necessitated by what proved to be some relatively ineffective adult trapping facilities within the subbasin itself (Bugert 1998), and caused unintended mixing of fish headed for spawning areas in the three major branches of the Methow system (Methow River, Chewuch River, and Twisp River). This mixing occurred despite efforts to assign broodstock to their intended destinations (NFMS et al. 1998; see Appendix Table A2).

Returns of adult spring Chinook to natural spawning areas in the Methow subbasin increased dramatically in the early 2000s in response to the same factors that affected salmon runs in the Wenatchee system: improved outmigration and ocean survival conditions as well the first truly large returns of adult fish that had been reared as juveniles by the integrated hatchery program operating within the subbasin. These returns were dominated by hatchery-origin fish, particularly in 2001 when nearly 10,000 adult Chinook salmon, the great majority of hatchery-origin, escaped to spawn. While spawning escapements of naturally produced adults last exceeded the ESA-related viability threshold recently established for the subbasin's spring Chinook (2000 fish; ICBTRT 2005) in 1978, hatchery-origin adults pushed total escapements above this level in both 2001 and 2002.

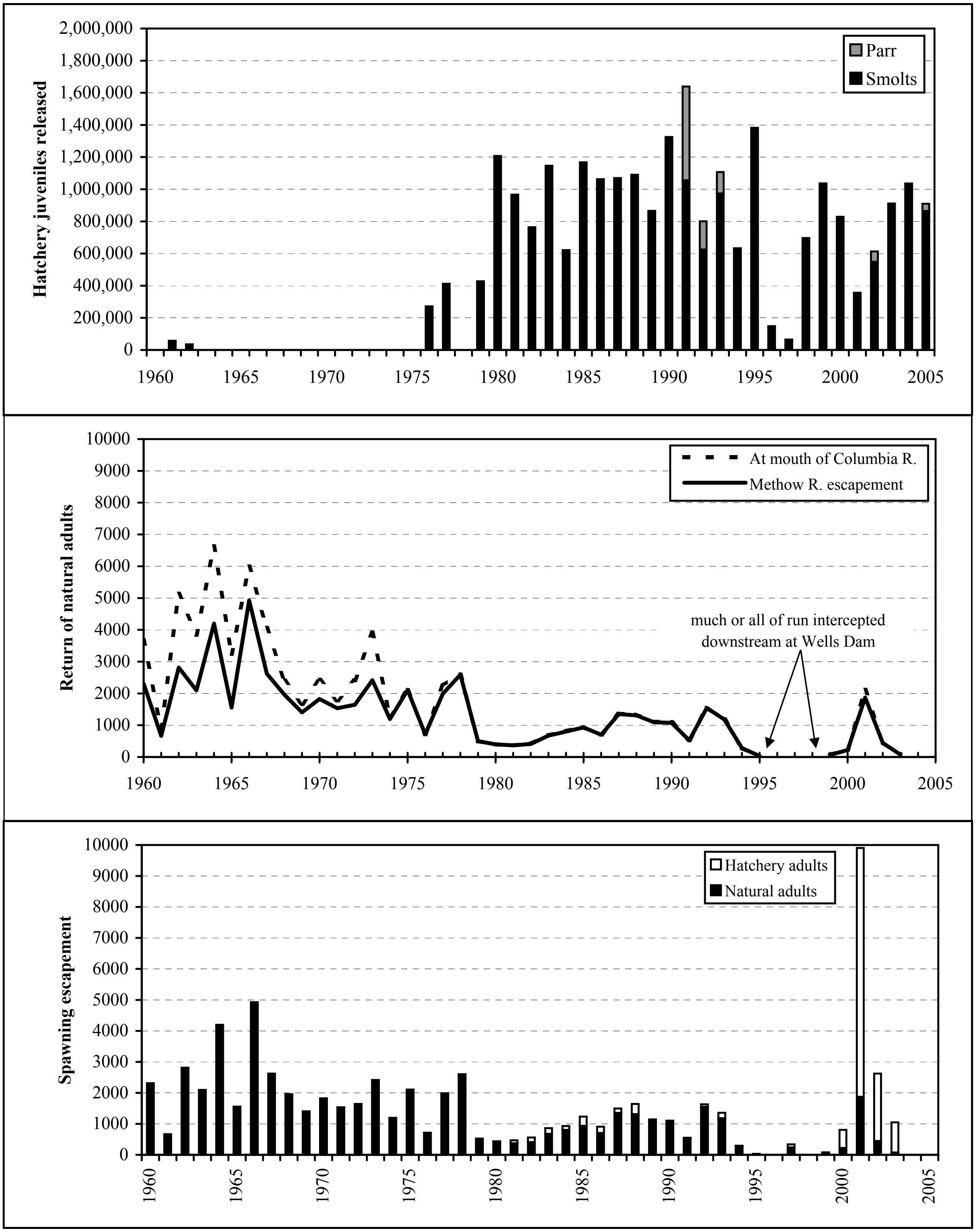


Figure 16. Hatchery releases, estimated returns of naturally produced adults, and estimated spawning escapements of hatchery and wild adults for spring chinook in the Methow River, 1960-2005.

Sources: Chapman et al. (1995), Fish Passage Center, Good et al. (2005), and UCSRB (2006).

Percentages of hatchery-origin fish in the Methow subbasin's natural spawning areas have stayed high since returns from the current integrated hatchery program (which has come to include both Winthrop NFH and Methow SFH) increased in 2000. During the most recent 5-year period for which data are available (2000-2004; see Appendix B), the percentage of hatchery-origin adults in the spawning escapement averaged 91% (range = 76-98%) on the Methow River, 75% (42-94%) on the Chewuch River, and 46% (27-96%) on the Twisp River. Spring Chinook in Twisp River, where adult collection has been most effective and releases of hatchery produced smolts smallest, have been least affected by high and disproportionate returns of hatchery-origin adults.

Infrastructure for collecting adult broodstock and for controlling the access of hatchery-origin returns to the major spawning areas along the Methow and Chewuch rivers remain insufficient for proper management of the integrated hatchery programs associated with those areas. This is a well-recognized problem of concern both to WDFW (2005) and to managers of Winthrop NFH, which produces more than half of the smolts released into the subbasin. Declining spring Chinook returns and high spring flows led managers to reinitiate adult collection efforts downstream at Wells Dam in 2006.

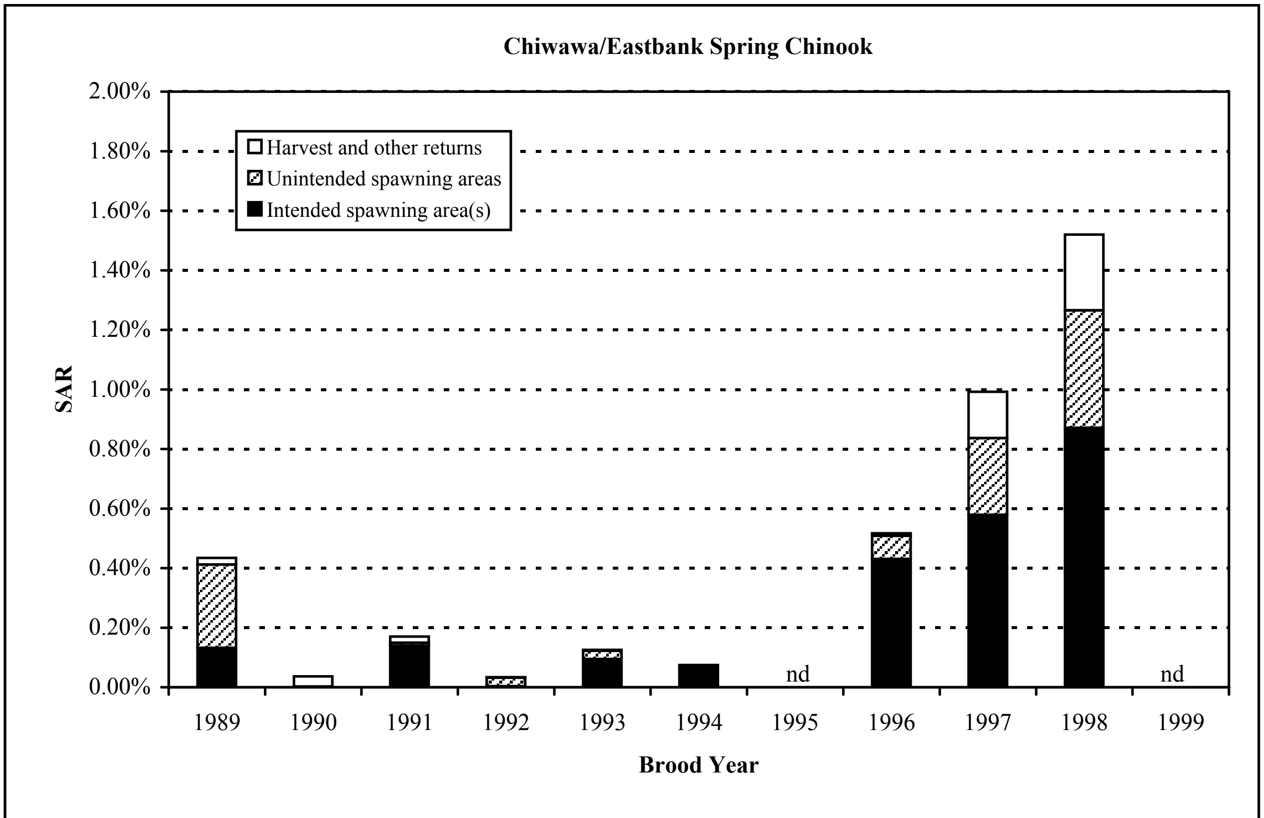
WDFW (2006) has recently proposed a harvest framework that would allow ESA-listed, hatchery-origin (marked) spring Chinook produced by the integrated program at Methow SFH and/or Winthrop NFH and returning to the system as adults to be caught and kept in a selective recreational fishery along a portion of the Methow River. The proposal is that the fishery be allowed if/when the abundance of these fish is predicted to be high enough to assure that at least 2,000 total spawners (hatchery-origin plus wild) will reach the subbasin's spawning areas, that at least 400 wild adults are in the run, and that at least 600 additional hatchery-origin adults will be available (apparently for potential use as hatchery broodstock). Per the proposal, allowed rates of incidental mortality for wild ESA-listed fish would range from 2% when the 400-800 wild adults were predicted to reach the subbasin to 10% when more than 2000 wild adults were predicted to be present. The proposal does not make clear whether levels of hatchery production in the subbasin will be reduced during any extended periods in which annual escapements of ESA-listed spring Chinook consistently exceed the fishery thresholds, as a way to increase opportunities for expansion of the naturally produced components of integrated groups of hatchery-origin and wild spawners.

Okanogan Subbasin. Spring Chinook have apparently been extirpated from the Okanogan River system, but the Colville Tribes are attempting to establish a fishery here. Initial hatchery releases of these fish into the Okanogan have been fish of Carson stock from facilities within the Leavenworth Complex. There has been some discussion about using "excess" hatchery-origin fish from the integrated program operating in the Methow subbasin, but tribal interest in using an ESA-listed stock from the Methow for the reintroduction effort is apparently contingent upon designating fish placed in the Okanogan an "experimental population" which would not be subject

<u>Recent Smolt-to-Adult Return Rates for Selected Hatchery-Produced Spring Chinook</u>. As indicated earlier, recent increases in the annual runs of adult spring Chinook in the Columbia Cascade Province have been strongly influenced by improved smolt-to-adult survival rates (SARs). This point has been clearly made by an analysis of tag return data for the Leavenworth, Entiat, and Winthrop NFHs completed by Cooper et al. (2006). Figure 17 shows recent annual variation in SARs for the integrated hatchery program on the Chiwawa River in the Wenatchee subbasin, and contrasts that program's SAR values with those for that subbasin's segregated hatchery program at Leavenworth NFH. Both programs returned adults at very low rates for at least a couple of early 1990s brood years, but substantial increases in SARs were seen for the offspring of fish spawned in both hatchery programs during brood years 1996-1998. These later brood years were those that contributed most to the upsurge in spring Chinook abundance observed in the early 2000s. The SAR data also make clear that (1) fish from the Chiwawa program often stray at high rates to spawn in streams (within the Wenatchee subbasin) other than the Chiwawa, and (2) post-release survival of the Chiwawa fish has frequently been lower than that for the Leavenworth fish. Poorer post-release survival of smolts has been noted in other situations where wild broodstock have been brought into a hatchery environment (M. Chilcote, ODFW, pers comm.), and has been suggested to reflect that the fish are more poorly adapted to a lifecycle passing through a hatchery than are long-cultured stocks of salmon.

Summer Chinook

Low escapements of the Province's summer Chinook salmon, affected by hydro-system mortality, habitat modification, and ocean fisheries (in-river harvests were negligible the last few decades but have slowly risen with recent upswings in abundance), led fish managers to increase their reliance on hatcheries to augment runs of these fish (Figure 18). Since the late-1980s, hatchery reared summer chinook smolts have been released into the lower reaches of the Province's larger Columbia River tributaries in an effort to offset hydro-system and harvest mortality, increase escapements, and (hopefully) increase natural production of summer chinook populations that were less abundant than desired. The hatchery programs focused on these summer chinook are large, and are producing year-old smolts from a race of fish whose juveniles historically left the Province as sub-yearling fish. In multiple years the programs have led to a predominance of adult hatchery-origin fish in the spawning areas along the namesake rivers of the Methow and Okanogan-Similkameen drainages.



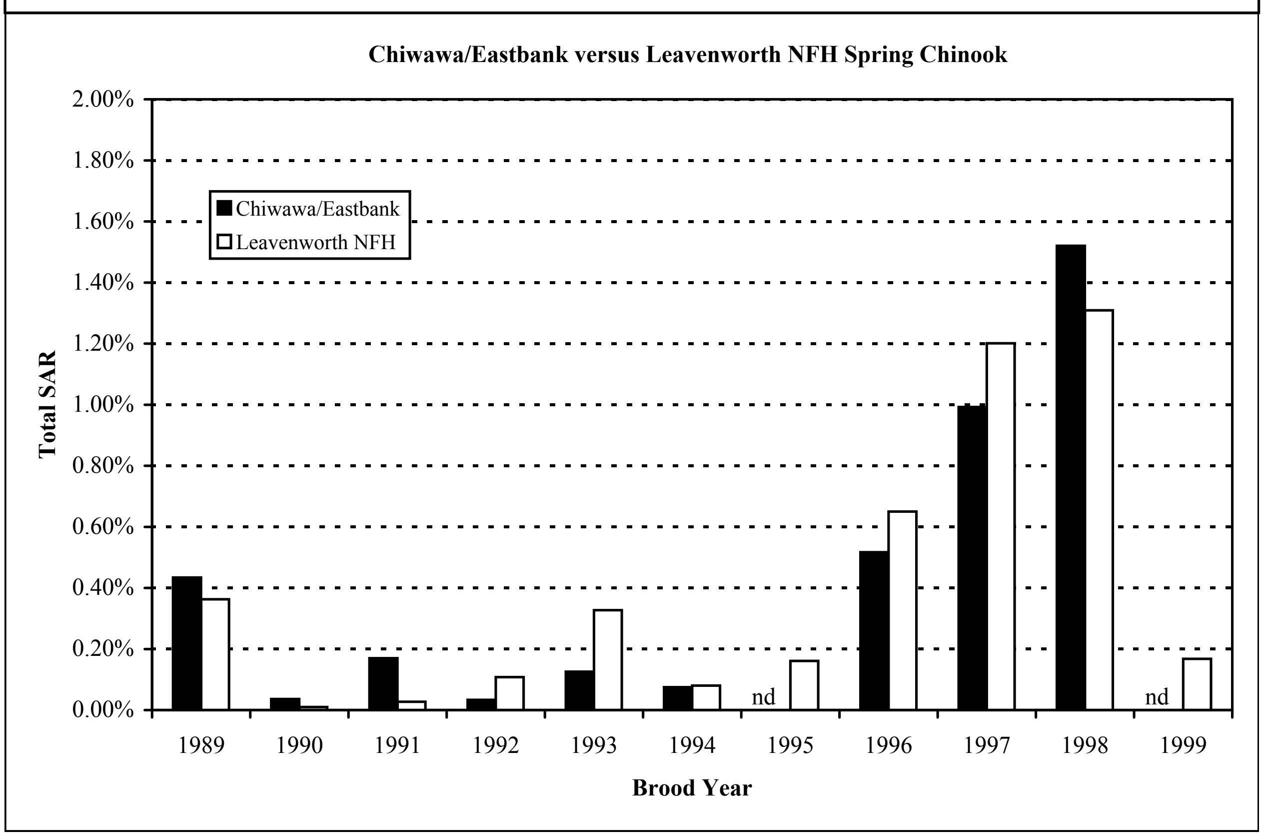
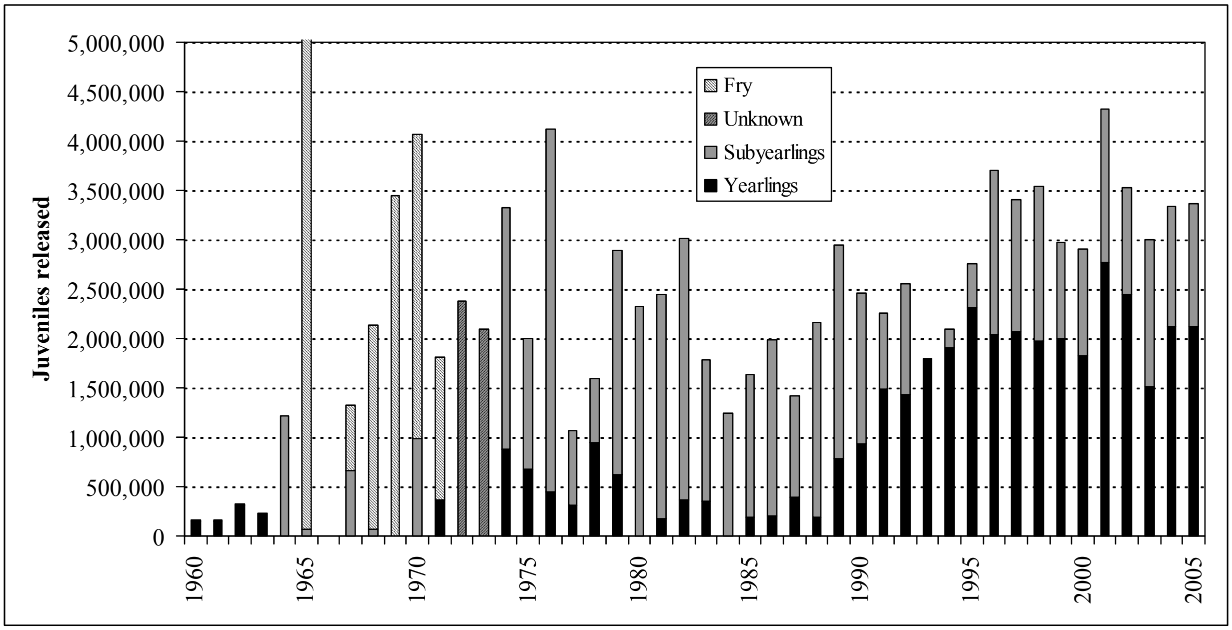


Figure 17. Smolt-to-adult return (SAR) values for the Chiwawa/Eastbank integrated spring chinook program, and a comparison to SARs for Leavenworth NFH spring chinook, brood years 1989-1999.

Source: RMIS.



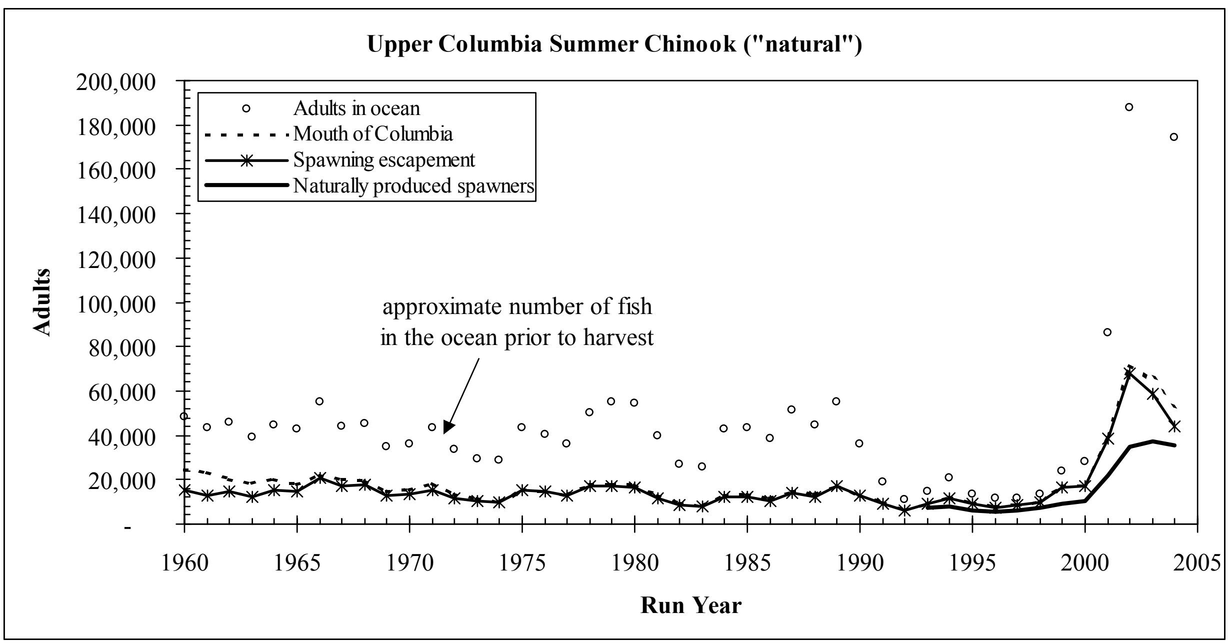


Figure 18. Hatchery releases (top) and adult returns (bottom) for Upper Columbia summer chinook salmon, 1960-2005. Sources: Waknitz et al. (1995), the Fish Passage Center, WDFW & ODFW (2002), PSC (2005a, 2005b), recent dam counts, recent annual WDFW hatchery return reports, and multiple PUD-sponsored spawning ground survey summaries. A steady increase from an approximately 50% ocean harvest rate in 1960 to earliest (and higher) rates reported by PSC (2005a) was assumed.

The long-term effects of these integrated programs on the natural productivity of the affected wild populations (i.e., that will express itself if the integrated hatchery programs end) are unknown but may well be negative in at least two cases due to frequently high proportions of hatchery-origin fish on the spawning grounds. The program operating in both the Methow and Okanogan subbasins is of particular concern because it collects a common broodstock for both subbasins downstream at Wells Dam, a situation that works against local adaptations in the receiving waters. It has been suggested that one or more of the programs could be enlarged as mitigation for ongoing salmon losses to the hydrosystem.

Results to date for these integrated summer chinook programs suggest what may be a relative boom-bust cycle. Hatchery-origin adult returns have been high when natural returns have been high, potentially leading to over-escapement and redd superimposition in some spawning areas. The hatchery-origin returns have also been substantially lower (but not insignificant) when natural returns were relatively low. The consequence of the program in the low return years may simply be to maintain sufficient spawning escapements of wild plus hatchery-origin fish in some of the tributaries to prevent further reductions in mixed stock ocean fisheries.

Recent SARs for fish produced by the Province's integrated summer Chinook programs have followed interannual patterns similar to those seen for the Province's spring Chinook programs, although the return rates for releases of yearling summer Chinook smolts have often been higher than the rates for yearling spring Chinook smolts (Figure 19). The SARs have been highest for summer Chinook smolts released into the Okanogan subbasin.

Sockeye salmon

Sockeye are less abundant within the Province than they were historically, but there is no indication that their populations are at risk. The Lake Wenatchee population has been classified as healthy in the past (Huntington et al. 1996) but a dramatic drop in escapements in the mid to late-1990s led WDFW (2002) to classify these fish as Depressed (Figure 20). A population within the Okanogan subbasin spawns in Canada and rears in Lake Osooyos, also in Canada, prior to migrating seaward. WDFW (2002) also classified that population as Depressed.

A relatively small integrated hatchery program for Lake Wenatchee sockeye currently uses net-pens floating in the lake to rear and release approximately 200,000 smolts per year from adults captured downstream on the Wenatchee River at Tumwater Dam. Adult return rates from these smolt releases have been quite variable among years, and returning hatchery-origin adults have

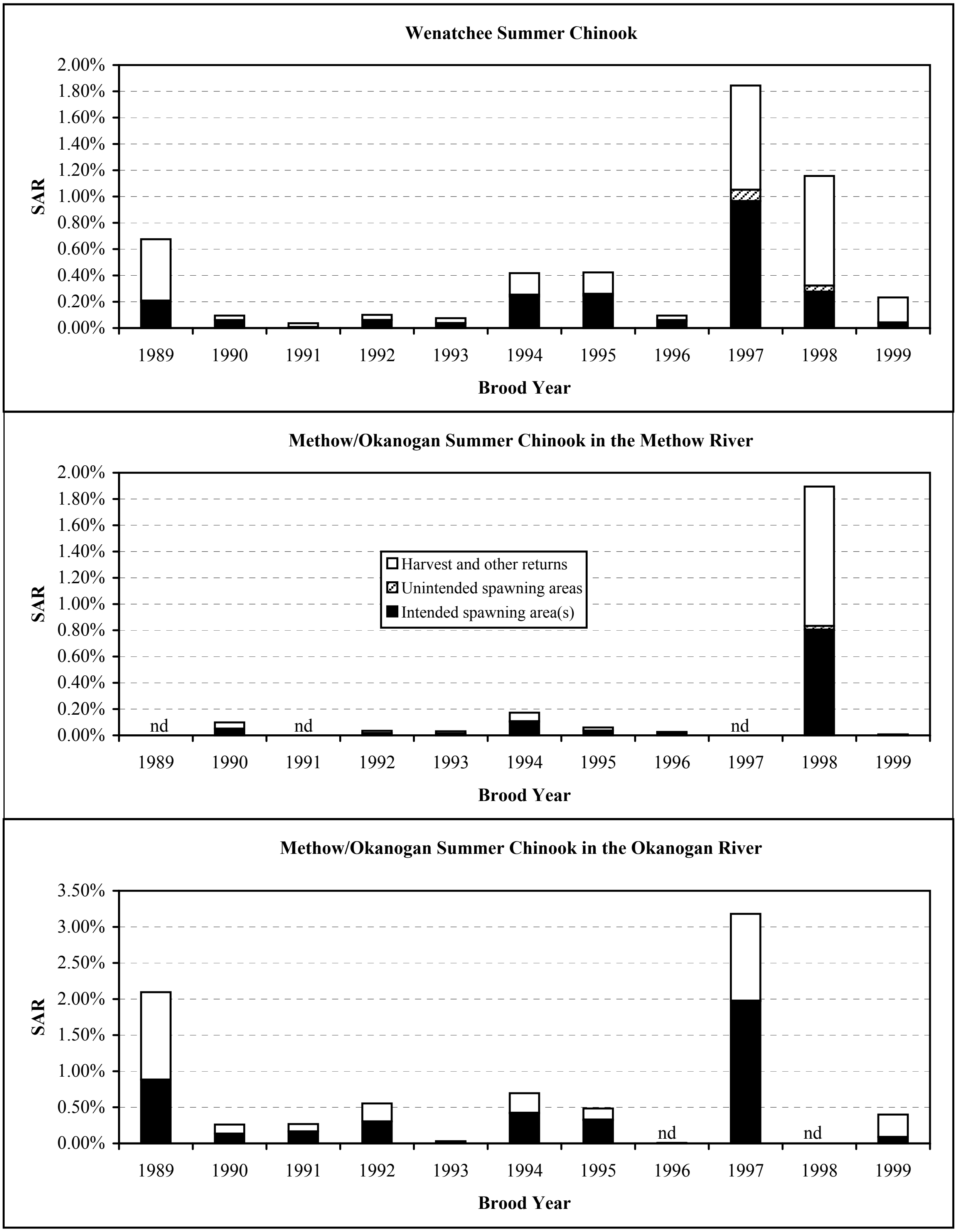
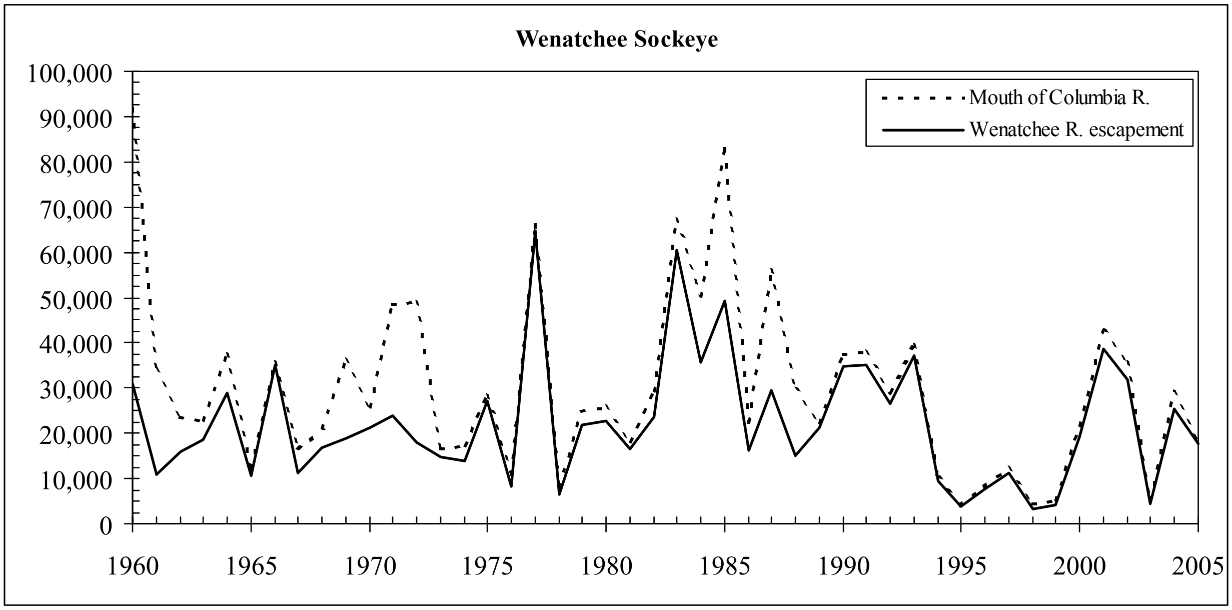


Figure 19. Smolt-to-adult return rates for releases from integrated summer chinook hatchery programs on the Wenatchee (top), Methow (middle), and Okanogan (bottom) rivers, 1989-1999. Source: RMIS.



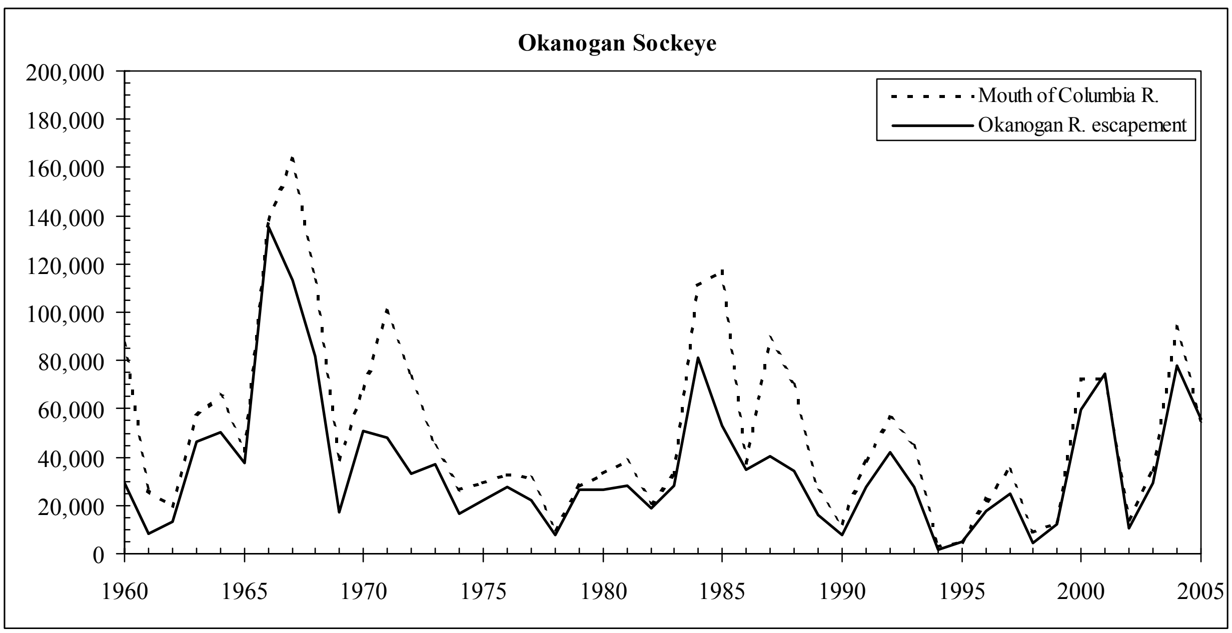


Figure 20. Estimated runs of sockeye salmon returning to the Wenatchee (top) and Okanogan (bottom) rivers, 1960-2005.

generally not been a large component of the naturally spawning population. Disease–related losses of adults collected as broodstock have been significant in some years because they are held in surface waters of Lake Wenatchee that can sometimes be warmer than is desirable (WDFW 2005). This is an issue that managers hope to rectify.

The intent of the integrated hatchery program for Lake Wenatchee sockeye is to augment harvest, particularly in a sport fishery active within the lake during years of strong adult returns. WDFW & ODFW (2006) provide data showing that sockeye harvests in areas downriver, between Priest Rapids Dam and the mouth of the Columbia, averaged 4.3% (range = 2.7-7.7%) during the last 10 years (1996-2005). The Lake Wenatchee sockeye program may be enlarged several-fold as mitigation for ongoing salmon losses to the hydrosystem (WDFW 2005; WDFW 2006).

Coho salmon

The Yakama Tribe, working with the USFWS and others, has initiated an effort to reintroduce coho salmon to the Province. The effort is in its early stages, rearing and releasing hatchery fish from the lower Columbia and trying to develop better adapted broodstock from the offspring of those fish that return to the area as adults. Some natural spawning and smolt production has occurred, but the effort is still in its infancy. Spawning escapement goals of 4,970 adult coho for the Wenatchee subbasin and 6,200 adults for the Methow system have been proposed, with broodstock collection goals for the artificial production programs in the two areas being 1,300 and 1,200 adults, respectively (WDFW 2006).

Summer steelhead

Natural runs of steelhead in the Columbia Cascade Province were ESA-listed as Endangered in August 1997, but their official listing status has since changed to Threatened. These fish have been dramatically affected by a long history of intensive, widely dispersed, hatchery supplementation in which the substantial majority of releases of hatchery fish have been off-site (Figure 21). Until recently, large numbers of yearling steelhead smolts artificially produced from adult fish captured in the vicinity of Wells Dam were planted each year in the Wenatchee, Entiat, Methow, and Okanogan subbasins. The consequence of this program is a group of steelhead populations in the area that appear to have largely been homogenized from a genetic standpoint (Chapman et al. 1994; Ford et al. 2001).

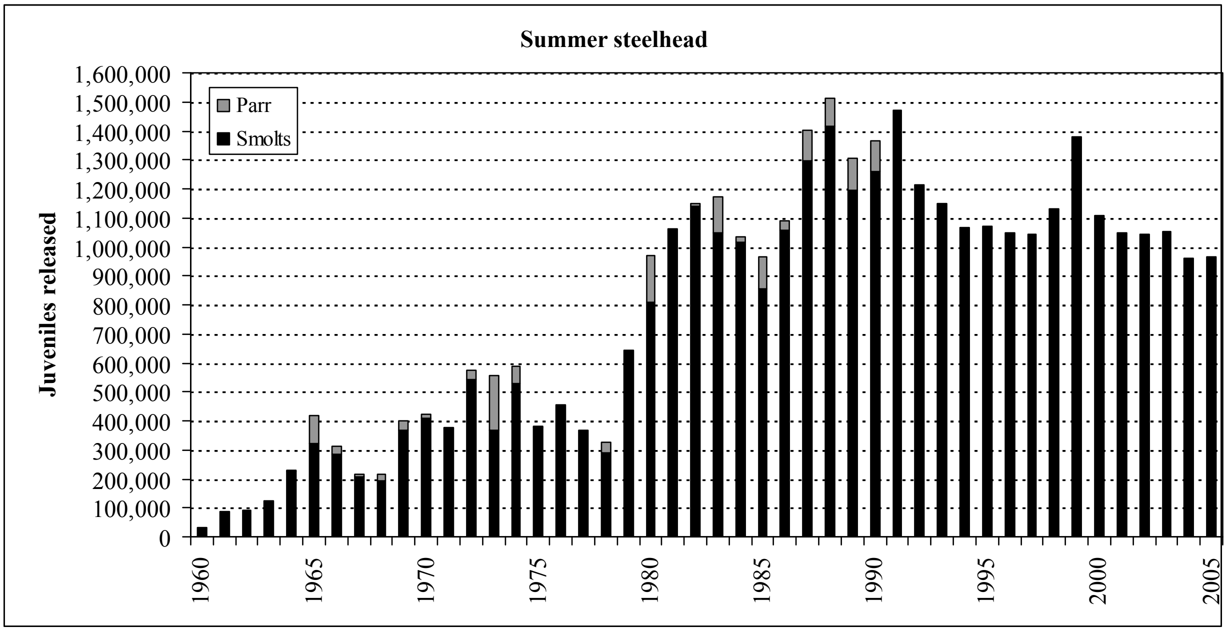


Figure 21. Releases of hatchery-reared summer steelhead into the Columbia Cascade Province, primarily through supplementation programs in Columbia River tributaries, 1960-2005. Source: Chapman et al. (1994) and the Fish Passage Center.

Hatchery-produced steelhead are no longer placed into the Entiat subbasin, because that area has been established as a reserve for this species, but modified versions of the historic program continue to release steelhead into the Wenatchee, Methow, and Okanogan systems (Figure 22). The new program in the Wenatchee subbasin has shifted to local broodstock as a conservation measure but has maintained a high artificial production target (400,000 smolts). Revised hatchery programs in the Methow (420,000 hatchery-produced smolts total) and Okanogan subbasins (130,000 smolts) are also moving toward development of local broodstock while maintaining their size, but are hindered by a lack of effective adult collection points upstream of Wells Dam. Until such local broodstock can be developed, wild fish captured at Wells Dam are being incorporated into the common hatchery broodstock used in the "integrated" program for those two subbasins. This works against the maintenance or development of local adaptation in the steelhead within the subbasins.

Available data on adult steelhead returns to the tributary subbasins of the Columbia Cascade Province are based largely on differences between dam counts made along the mainstem Columbia River and harvest records. These data make it possible to reconstruct time series of approximate adult returns to a geographic composite of the Wenatchee and Entiat subbasins and to another composite that includes both the Methow and Okanogan subbasins (Figure 23). Steelhead runs within the Province have become dominated by hatchery fish, with the degree of this dominance considerably stronger for the Methow-Okanogan composite, above 9 hydroelectric dams, than it is for the Wenatchee-Entiat composite, above 7-8 dams. In both

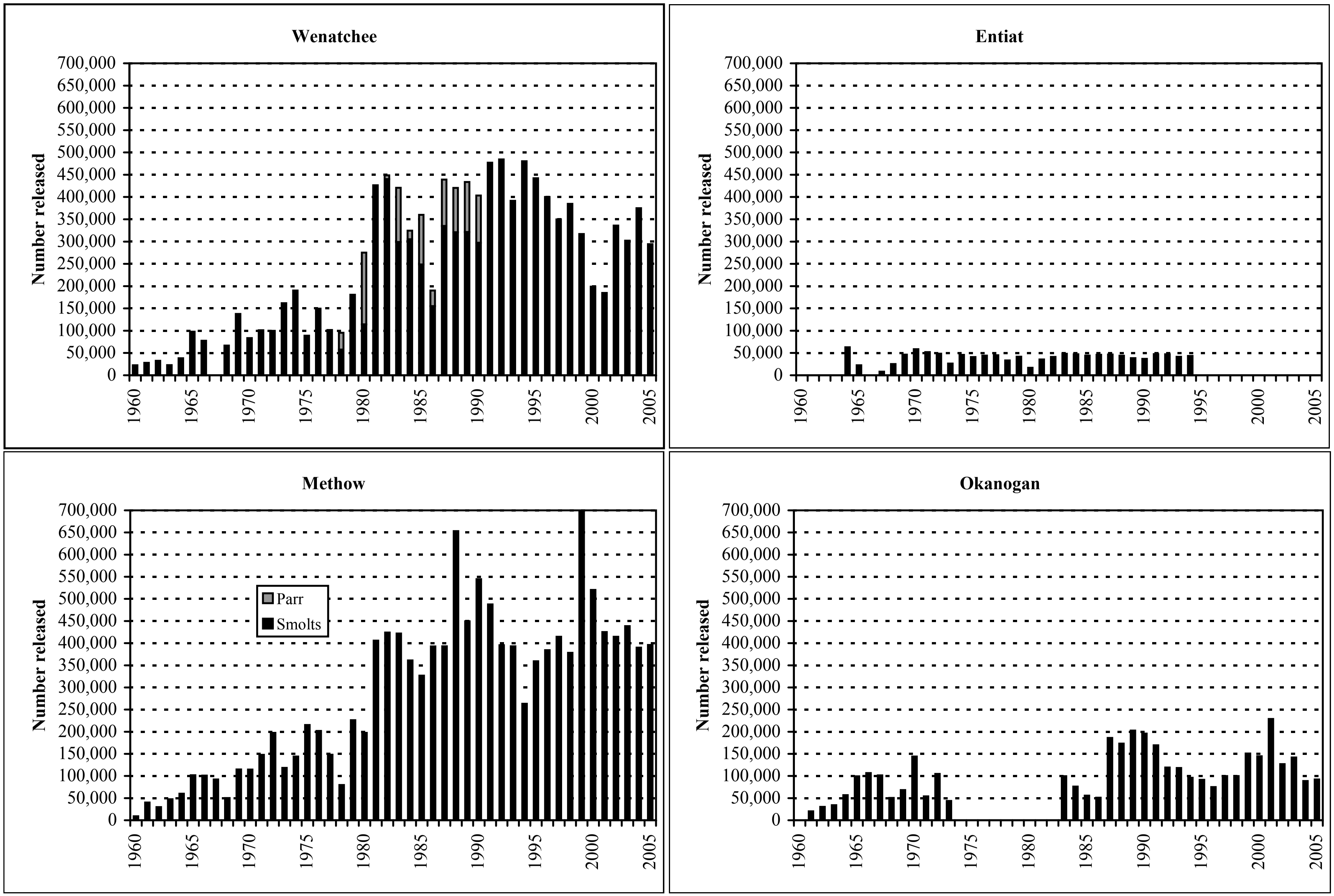


Figure 22. Numbers of hatchery-reared summer steelhead released into specific tributary subbasins within the Columbia Cascade Province, 1960-2005. Sources: Chapman et al. (1994) and the Fish Passage Center.

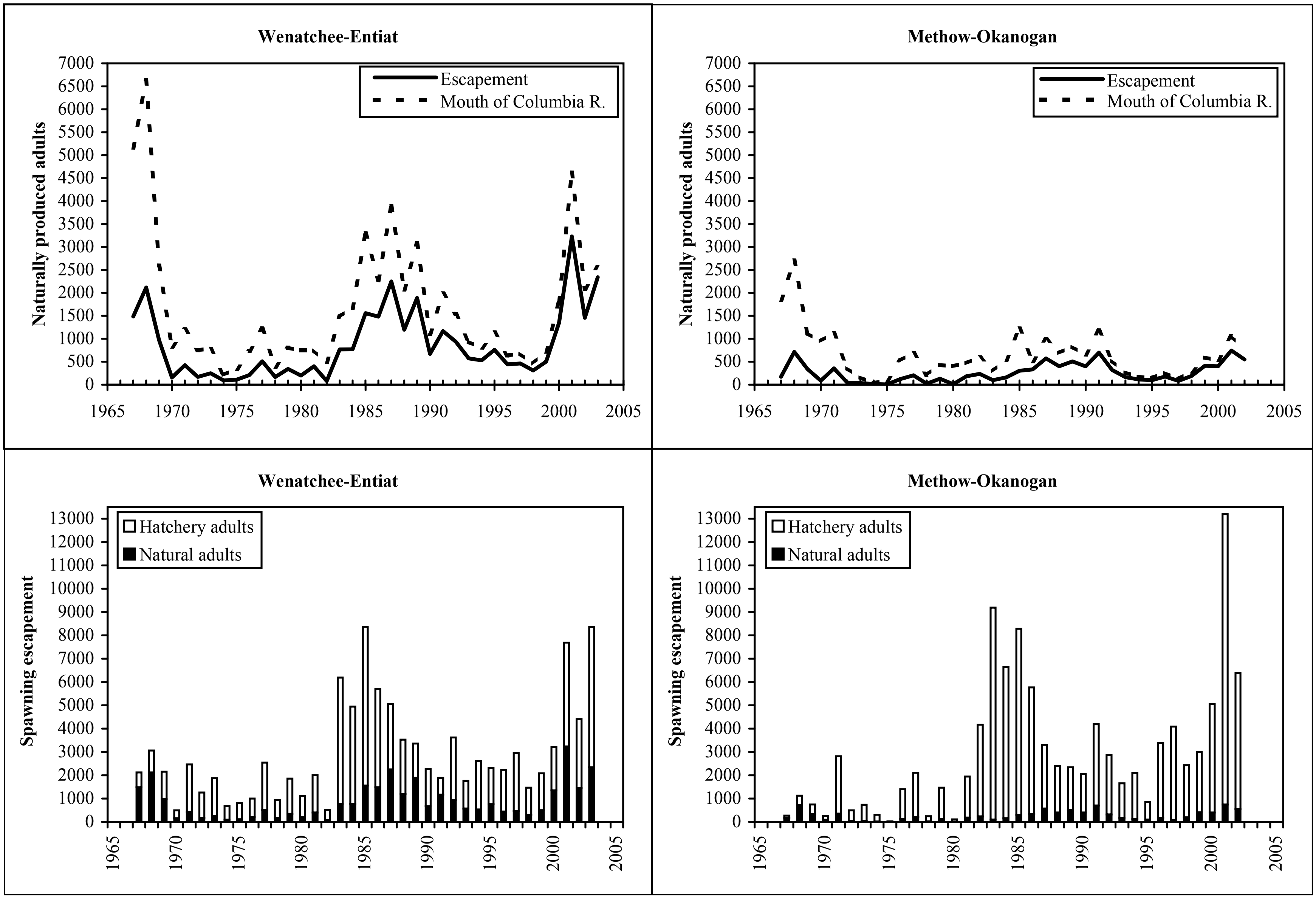


Figure 23. Estimated returns of naturally produced adults (top), and spawning escapements of hatchery and wild adults (bottom), for summer steelhead in the Wenatchee-Entiat (left) and Methow-Okanogan (right) systems, 1967-2003. Sources: UCSRB (2006), WDFW and ODFW (2002).

cases, the large size of the hatchery programs may be an impediment to the recovery of self-sustaining populations of steelhead.

Ford et al. (2001) recommended interim abundance targets of 2500 naturally produced steelhead returning to each of the Wenatchee and Methow subbasins, and another 500 to the Entiat subbasin. More recently, ESA-related viability thresholds for the abundance of the Province's steelhead populations have been estimated as 1,500 self-sustaining adults each in the Wenatchee and Methow subbasins, 500 in the Entiat system, and 1,000 in the Okanogan (ICBTRT 2005). WDFW (2006) has proposed limited selective recreational fisheries on the hatchery-origin (but ESA-listed) steelhead that return to the Province provided that returns of naturally produced (unmarked wild) adults exceed 1,300 and the total steelhead run over Priest Rapids Dam (downstream) exceeds a total of 9,550 wild plus hatchery-origin adults. Allowed levels of predicted incidental take (mortality) of the wild component of the run would vary among geographic areas and would depend on the degree to which the wild component exceeded the minimums identified above. The proposed maximum rates of incidental take would be 2-6% of the wild component returning to most geographic areas within the Columbia Cascade Province and 5-10% of the wild component returning to the Okanogan subbasin. The highest levels of take would occur only when the naturally produced components of the run were of the magnitude suggested by Ford et al. (2001).

HATCHERY PROGRAMS IN THE COLUMBIA CASCADE PROVINCE

Hatchery programs currently operating or proposed within the Columbia Cascade Province were assessed for the degree to which they reflected some or all of the "landscape perspective" that Williams et al. (2003) and others have suggested will be critical to the appropriate and effective future use of hatcheries. The assessment was based on five elements of each program: spatial context, scale, duration, adult salmon management, and juvenile rearing. Information sources relied upon in the assessment are summarized in Appendix B.

Assessment Elements

Spatial Context. The spatial context of each hatchery program was assessed on the basis of two factors. The first factor was consistency with general guidance set out in the 2000 Columbia River Basin Fish and Wildlife Program (NPPC 2000) for uses of hatcheries in the CRB (Table 1). Consistency with this guidance was judged on the basis of whether there was a match between watershed-level conservation opportunities or strategies identified during recent planning efforts (UCRTT 2002; UCSRB 2006; Figure 24), and the hatchery program under consideration. Segregated hatchery programs releasing fish into areas other than locations

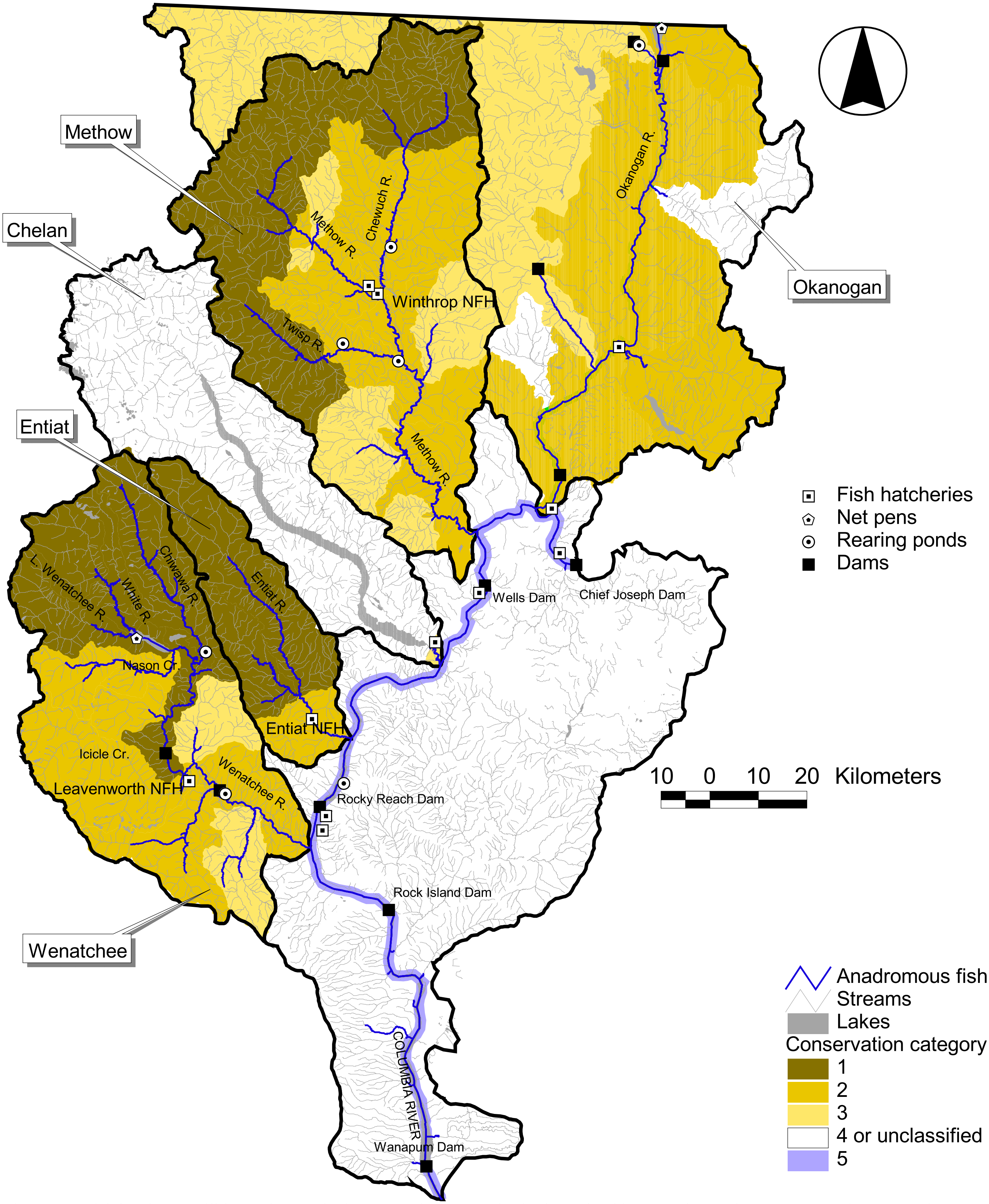


Figure 24. Fish hatchery facilities and watershed conservation categories in the Columbia Cascade Province. Conservation categories, based on UCRTT (2002) and UCSRB (2006), are Intact (1), Restorable (2), Moderately Compromised (3), Substantially Compromised (4), and Columbia River (altered but critical; 5).

immediately downstream of dam-blocked habitat or into fundamentally altered habitats (e.g., the mainstem Columbia River) were considered out of context (***Inconsistent***).

Table 1. Relationship between habitat condition and artificial production strategies specified in the Northwest Power Planning Council's 2000 Fish and Wildlife Program (NPPC 2000). In the assessment described here, the term "supplementation" was taken to represent the possibility of an integrated hatchery program and the term "replacement hatchery" was taken to describe a segregated program.

Criteria			**Examples of strategies**	
Habitat condition	**Description**	**Biological potential of target species**	**Habitat strategy**	**Possible artificial production strategy**
Intact	Ecological functions and habitat structure largely intact	High	Preserve	No artificial production
		Low	Preserve	Limited supplementation
Restorable	Potentially restorable to intact status through conventional approaches	High	Restore to intact	Interim supplementation
		Low	Restore to intact	Limited supplementation
Compromised	Ecological functions or habitat structure substantially diminished	High	Moderate restore	Limited supplementation
		Low	Moderate restore	Supplementation
Eliminated	Habitat fundamentally altered or blocked without feasible recovery options	High	Substitute	Replacement hatchery
		Low	Substitute	Replacement hatchery

The second factor affecting a program's spatial context was whether it was functioning in an area that allowed it either to provide conservation benefits or to avoid impeding conservation efforts. With respect to this factor, programs whose infrastructure or other characteristics caused direct geographic transfers of ESA-listed fish to areas away from their associated natural populations were considered out of context (***Inconsistent***). A contextual rating of ***Uncertain*** was assigned to integrated programs if they were focused on augmenting harvests of the area's relatively strongest salmon populations without providing clear conservation benefits. This rating was assigned despite a lack of inconsistency with the NPPC (2000) guidelines because such programs tend (1) to suggest that problems affecting the area's weaker stocks are not being effectively addressed, and (2) to have the potential to reduce natural population productivity while obscuring true population status. Similarly, integrated programs with common geographies and species were classified as of ***Uncertain*** spatial context because their management tends to be confounded.

A qualification to the context ratings assigned seems important. The general guidance for suitable artificial production strategies as outlined in Table 1 should be viewed as identifying areas where integrated hatchery programs might be appropriate, not where they necessarily should be applied. For such programs to be employed in a fully proper context, they should be accompanied by meaningful watershed reserves.

Scale. The scale of each hatchery program was classified into one of four categories, based on a rough assessment of its size relative to the magnitude of historic and recent smolt production potential within various parts of the Columbia Cascade Province and Upper Columbia basin (see Appendix Tables A3 and A4). There is some disagreement on the degree to which releases of migratory, hatchery-reared smolts have unfavorable ecological effects (competition, predation, disease transfer, etc.) upon naturally produced juvenile salmonids within migratory corridors upstream of the Columbia River estuary. However, it is reasonable to conclude that the potential for, and magnitude of, any such effects would increase with the abundance of fish released relative to the numbers of naturally produced fish that either passed down these corridors historically, or that accessible habitat might produce to migrate down them naturally at present. Also, upon their return as hatchery-origin adults, the fish released will become part of the ecological landscape of the watershed into which they were placed. As such, over-abundant returns of hatchery-origin adults may depress the survival rates of wild fish through density-dependent interactions (competition) that can occur among their offspring. With these consideration in mind, program size was classified as indicated below, with the size classification assigned a given program being the largest one appropriate:

- ***Small*** -- The program's annual production objective for hatchery smolts of the species and age of interest is small relatively to recent natural production of similar smolts upstream of the release point(s), and in combination with that natural production does not exceed the estimated recent natural smolt production capacity of the upstream areas.

- ***Moderate*** -- The program's annual production objective for hatchery smolts of the species and age of interest, in combination with the recent production of similar smolts upstream of the release point(s), does not exceed the historic number estimated to have passed by the release location.

- ***Large*** -- The program's annual production objective for hatchery smolts of the species and age of interest, in combination with the recent annual production of smolts of this species and age in areas upstream of the release point(s), exceeds the historic number estimated to have passed by the release location.

- ***Very large*** -- The program's annual production objective for hatchery smolts of the species and age of interest by itself exceeds the historic number estimated to have passed by the release location.

Estimates of smolt production potential used to help rate the scale of individual programs are given in Appendix Tables A3 and A4.

Duration. As has been indicated, the duration of a hatchery program can affect its conservation benefits and risks. Each program in the Province was rated as being of explicitly ***limited*** duration, of ***indefinite*** (and apparently extended) duration, or (as is the case for Leavenworth Complex programs) ***in review***.

Management of Adult Salmon. The HSRG (2005) has recommended minimum hatchery "best management practices" (BMPs) for managing adult salmon in hatchery broodstock and on the spawning grounds. These BMPs are intended to control the degree to which artificial selection associated with fish culture activities will reduce fitness in the wild over time for naturally spawning salmon populations, and to provide an objective (if imperfect) basis for assessing whether hatchery programs are managing adult fish in a way consistent with species conservation. They are intended by the HSRG (2005) to limit the erosion of natural fitness in the affected salmon populations and guide long-term or permanent programs where hatchery and naturally-produced salmon will breed with one another by design.

For segregated hatchery programs, the HSRG-recommended BMP for adult salmon management is that fewer than 5% of the fish in natural spawning areas should be hatchery-origin spawners (pHOS<5% or >95% wild/natural adults in spawning areas). For integrated programs, their BMP is that the percentage of natural-origin broodstock (pNOB) used in the hatchery program should be higher than pHOS in the associated natural spawning area(s), and substantially so where conservation of the biological characteristics of the natural salmon population involved is of high priority. To further clarify the need for integrated hatchery programs to manage the interbreeding of hatchery and natural-origin salmon, the HSRG (2005) developed a Percent Natural Influence (PNI) index as a way to characterize integrated hatchery programs [calculated as PNI = 1-pNOB/(pNOB+pHOS)] and suggested that values of this index should be greater than 0.7 where conservation is a priority.

While recognizing the experimental nature of integrated hatchery programs as a conservation tool, I adopted the just-discussed BMPs for managing the breeding of naturally produced and hatchery-origin salmon and then used them to help evaluate individual Columbia Cascade Province hatchery programs, with one caveat. The available science suggests that integrated hatchery programs will likely reduce fitness in the wild of natural salmon populations over time, with the degree of loss unknown but potentially substantial (see, for example, Ford 2002 and Goodman 2005). Where such integrated programs are intended to emphasize species

<u>conservation and not be permanent, their PNI should be kept as high as possible and their duration should be limited to the degree practicable</u>.

After reviewing available information, the ratings assigned to hatchery programs for their management of adult salmon were as follows:

- ***Good*** – Meets or exceeds the adult management BMP for a program of its type, and does not have known problems associated with broodstock mating protocols, disease transfers, or intermittent but substantial losses of adult broodstock.

- ***Imperfect*** – Fails to meet the adult management BMP for a program of its type, or has known problems associated with disease transfers or intermittent but substantial losses of adult broodstock.

- ***Flawed*** – An integrated hatchery program that collects adults from multiple natural populations, sometimes at a substantial distance from natural spawning areas, and incorporates them with hatchery fish into a mixed-origin broodstock for use in supplementing natural spawning areas. Management of this kind impairs local adaptation and diverse, productive natural populations.

- ***Unknown*** – Segregated programs for which natural spawning by adult hatchery-origin fish needs further evaluation, or a new or proposed program with little or no history of operation were assigned this classification.

As this program element was rated for the Province's hatcheries, it became clear that adult salmon management associated with most of them has not been consistent with the BMPs identified by the HSRG (2005). Few programs I was able to assess, including those of the Leavenworth NFH Complex and others associated with ESA-listed salmon, meet the BMPs (Figure 25). One cause of this situation seems to be that while changes in broodstock management within hatcheries are favored by managers, fully functional infrastructure for controlling hatchery-origin salmon and limiting their use of natural spawning areas is often lacking. Another contributor is an interest by some to see more salmon, regardless of their hatchery or natural origins, on the spawning grounds, although this view may be changing as new research continues to show hatchery-origin spawners to have the potential to reduce the fitness of natural populations. The option of reducing the size of individual and aggregate releases of hatchery-produced fish from programs whose adult fish are more abundant than desired in natural spawning areas does not generally seem to have been adopted, at least as of yet.

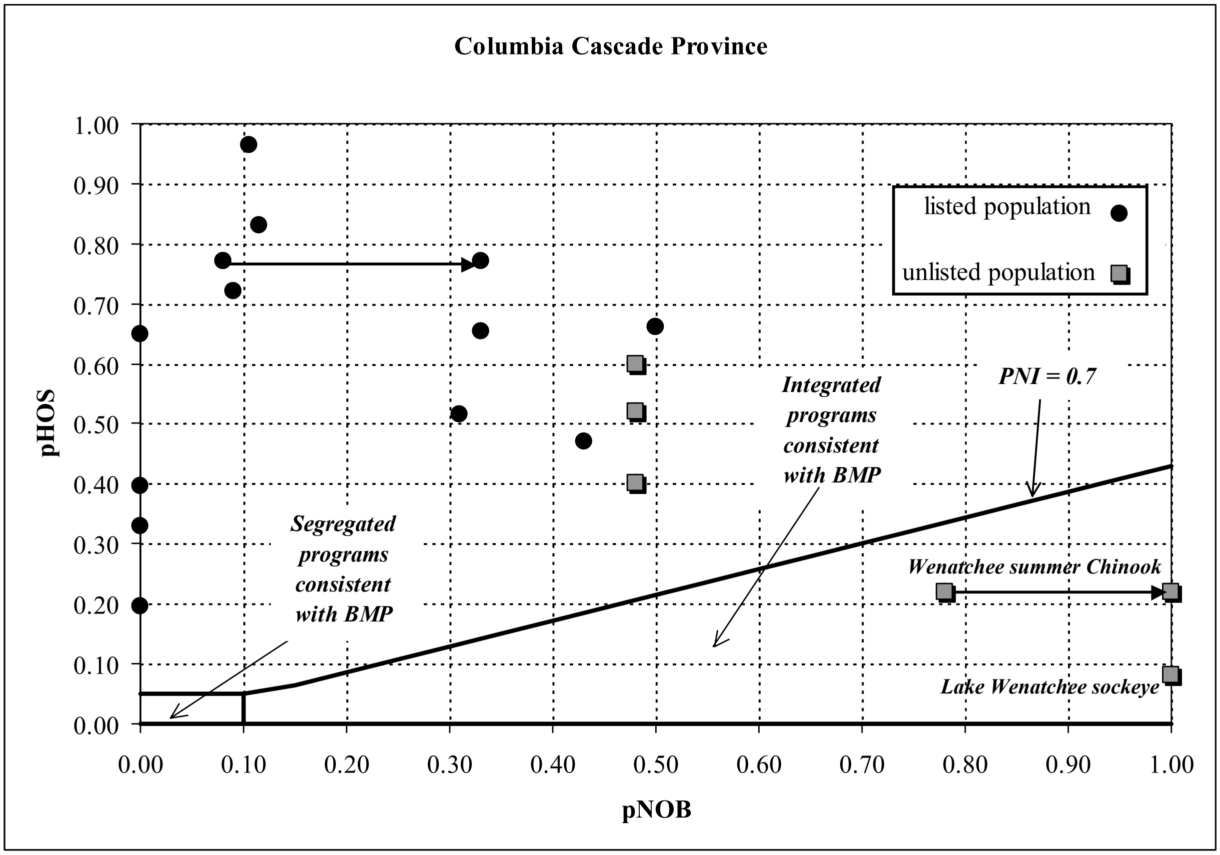


Figure 25. Adult salmon management by existing Columbia Cascade Province hatchery programs: percent hatchery-origin fish on the natural spawning grounds (pHOS) versus the percent natural-origin adults in the hatchery broodstock (pNOB). Programs are distinguished by the ESA-listing status of the natural salmon population with which they are associated. Bold arrows identify recently instituted improvements to programs. The adult salmon management of multiple programs has not been evaluated.

Juvenile rearing. Williams et al. (2003), Flagg et al. (2000), and others have indicated that conservation-oriented hatcheries need to modify their rearing protocols so as to produce juvenile salmon that are physically, physiologically, and behaviorally similar to naturally produced juveniles. The basis for this need is a desire to reduce differences in selection pressures between the two environments so as to help minimize reductions in the natural fitness of hatchery-origin fish, and to produce fish that will survive at higher rates post-release so that similar numbers of returning adults can be produced from fewer smolts. Producing hatchery-origin fish fit for the natural environment of a population's home watershed is of particular importance for integrated programs where maintenance of such fitness in the population as a whole is of paramount concern. Releases of fewer hatchery-produced smolts would, in turn, reduce the potential for interactions between them and naturally produced ones in downstream areas. These types of changes would require the use of a variety of progressive rearing techniques that differ to varying degrees from the conventional techniques long used in production-focused hatcheries.

Juvenile rearing by each of the individual fish hatchery programs in the Province was classified into one of three categories: ***progressive***, ***conventional***, or ***mixed***. Progressive rearing represented something reasonably close to the ideal Williams et al. (2003) describe for a conservation-oriented program, and included the types of changes from conventional rearing suggested by Flagg et al. (2000). Programs with conventional rearing methods conducted industrial-scale rearing in concrete raceways with limited attention to mimicking conditions in the natural environment. Programs with mixed rearing protocols had characteristics of both conventional and progressive programs, with their progressive elements including the use of acclimation ponds near release points, earthen juvenile rearing areas, and/or the release of fish that volitionally exited the hatchery's rearing environment. Programs classified as mixed tended to be considerably more conventional than progressive.

Assessment Results

The segregated and integrated hatchery programs operating within the Columbia Cascade Province were assessed relative to the elements outlined in the previous section, to develop a clearer sense of how the programs are operating and how their operations might affect options for reconfiguring hatchery programs at the Leavenworth Complex facilities. Relationships between the various hatchery programs and the natural salmon populations within the Province are outlined in Table 2. Individual hatchery programs and their ratings on the five assessment elements are summarized in Table 3.

One of the most striking results of the assessment was that there are very few wild populations or segments of wild populations of anadromous salmonids within the subbasins tributary to the upper Columbia that are not directly affected by some form of integrated hatchery program. For the area's ESA-listed species of these fish, the only reserves are the Entiat subbasin for summer steelhead and the Little Wenatchee watershed (in the Wenatchee subbasin) for spring chinook. Hatchery releases of steelhead into the Entiat were terminated in the 1990s. The Little Wenatchee has critically low adult returns that account for a very small fraction of the annual run of naturally produced adult spring chinook up the Wenatchee River.

Hatchery programs in the Province are generally quite large and are not clearly intended to function for less than an extended period of time. Few for which assessments have been conducted are meeting the HSRG's (2005) BMPs for managing breeding between hatchery-

Table 2. Natural populations of anadromous salmonids and hatchery programs in the Columbia Cascade Province.

Species	Subbasin-level population	Natural population segment(s)	Status	Predominant habitat condition(s) for species in home watershed	Existing hatchery programs directly associated with population segments: Primary fish hatchery	Program type	Primary purpose(s)
Spring chinook salmon	Wenatchee	Chiwawa R.	Endangered	Intact	Eastbank SFH	Integrated	Experimental conservation, mitigation for mainstem dams
		Nason Cr.	Endangered	Restorable	Aqua Seed, Inc.	Transitional*	Experimental conservation, mitigation for mainstem dams
		White R.	Endangered	Intact	Aqua Seed, Inc.	Transitional*	Experimental conservation, mitigation for mainstem dams
		Little Wenatchee R.	Endangered	Intact	---	None	---
		Icicle Cr.	---	Restorable	Leavenworth NFH	Segregated	Harvest mitigation for dam-blocked habitat
		Other tributaries	---	Restorable / compromised	Leavenworth NFH	Mixed	Experimental repopulation
	Entiat	Entiat R.	Endangered	Intact / restorable	Entiat NFH	Segregated	Harvest mitigation for dam-blocked habitat
	Methow	Methow R.	Endangered	Intact / restorable	Methow SFH and Winthrop NFH	Integrated	Experimental conservation, mitigation for mainstem dams and mitigation for dam-blocked habitat
		Twisp R.	Endangered	Intact / restorable	Methow SFH	Integrated	Experimental conservation, mitigation for mainstem dams
		Chewuch R.	Endangered	Intact / restorable	Methow SFH	Integrated	Experimental conservation, mitigation for mainstem dams
	Okanogan	Okanogan R.	Extinct	Restorable / compromised	---	---	---
Summer chinook salmon	Wenatchee	Wenatchee R.	Not listed	Restorable	Eastbank SFH	Integrated	Harvest mitigation for mainstem dams
	Entiat	Entiat R.	Extinct	Restorable	---	None	---
	Methow	Methow R.	Not listed	Restorable	Eastbank SFH	Integrated	Harvest mitigation for mainstem dams
	Okanogan	Okanogan R.	Not listed	Restorable	Eastbank SFH	Integrated	Harvest mitigation for mainstem dams
Sockeye salmon	Wenatchee	Lake Wenatchee	Not listed	Intact	Eastbank SFH	Integrated	Harvest mitigation for mainstem dams
	Okanogan	Osoyoos Lake	Not listed	Restorable	Cassimer Bar FH	Integrated	Harvest mitigation for mainstem dams
Coho salmon	Wenatchee	Wenatchee R.	Extinct	Restorable	Leavenworth NFH	Segregated	Experimental reintroduction (stock development phase)
	Entiat	Entiat R.	Extinct	Restorable	---	None	---
	Methow	Methow R.	Extinct	Restorable	Winthrop NFH	Segregated	Experimental reintroduction (stock development phase)
Summer steelhead	Wenatchee	Wenatchee R.	Threatened	Intact/restorable	Eastbank SFH	Integrated	Experimental conservation, mitigation for mainstem dams
	Entiat	Entiat R.	Threatened	Intact/restorable	---	None	---
	Methow	Methow R.	Threatened	Intact/restorable	Wells SFH	Integrated	Experimental conservation, mitigation for mainstem dams
	Okanogan	Okanogan R.	Threatened	Restorable/compromised	Wells SFH	Integrated	Experimental conservation, mitigation for mainstem dams

* "Transitional" programs are currently captive brood operations, but are apparently slated for transition into integrated hatchery programs.

Table 3. Characterization of anadromous salmonid hatchery programs and their elements, Columbia Cascade Province.

Species	Subbasin	Primary hatchery facility	Program type	Magnitude of artificial production[1]: Broodstock collection target (adults)	Magnitude of artificial production[1]: Production objective (smolts)	Program elements: Spatial context	Program elements: Scale	Program elements: Duration	Program elements: Adult management	Program elements: Juvenile rearing
Spring chinook salmon	Mainstem Columbia	Chief Joseph FH	Segregated	(426)	(600,000)	Consistent	Moderate	Indefinite	Unknown	Conventional
	Wenatchee	Chiwawa/ Eastbank SFH	Integrated	379	672,000	Consistent	Very large[2]	Indefinite	Imperfect	Mixed
		White River/Aqua Seed, Inc.	Transitional	---	150,000[a]	Consistent	Increasing	Indefinite	Imperfect	Mixed
		Nason Creek/Aqua Seed, Inc.	Transitional	---	250,000[a]	Consistent	Increasing	Indefinite	Imperfect	Mixed
		Leavenworth NFH	Segregated	1000	1,625,000	Inconsistent	Very large	In review	Imperfect	Conventional
	Entiat	Entiat NFH	Segregated	250	400,000	Inconsistent	Very large	In review	Imperfect	Conventional
	Methow	Winthrop NFH	Integrated	362	600,000	Inconsistent	Very large	In review	Flawed	Conventional
		Methow SFH	Integrated	306	550,000	Inconsistent	Very large	Indefinite	Flawed	Mixed
	Okanogan	Chief Joseph FH	Integrated	(214)	(300,000)	Consistent	Large	Indefinite	Unknown	Mixed
Summer chinook salmon	Mainstem Columbia	Chief Joseph FH	Segregated	(416)	(900,000)	Consistent	Moderate	Indefinite	Unknown	Conventional
		Wells SFH	Segregated	441	804,000	Consistent	Moderate	Indefinite	Unknown	Mixed
		Turtle Rock/ Rocky Reach	Segregated	980	1,820,000	Consistent	Moderate	Indefinite	Unknown	Conventional
	Wenatchee	Eastbank SFH	Integrated	492	864,000	Uncertain	Very large	Indefinite	Good	Mixed
	Entiat	---	None	---	---	Consistent	---	---	---	---
	Chelan	Chelan SFH	Segregated	(85)	(150,000)	Consistent	Very large	Indefinite	Unknown	Conventional
	Methow	Eastbank SFH	Integrated	228	400,000	Uncertain	Very large	Indefinite	Flawed	Mixed
	Okanogan	Eastbank SFH	Integrated	328	576,000	Uncertain	Very large	Indefinite	Flawed	Mixed
		Chief Joseph FH	Integrated	(710)	(1,100,000)	Uncertain	Very large	Indefinite	Unknown	Mixed
Sockeye salmon	Wenatchee	Eastbank SFH	Integrated	260	200,000	Uncertain	Small	Indefinite	Imperfect	Mixed + (netpens)
Coho salmon	Wenatchee	Leavenworth NFH	Integrated	---	1,000,000	Consistent	Very large	In review	Unknown	Mixed
	Entiat	---	None	---	---	Consistent	---	---	---	---
	Methow	Winthrop NFH	Segregated	280	250,000	Consistent	Large	In review	Unknown	Mixed
Summer steelhead	Wenatchee	Eastbank SFH	Integrated	208	400,000	Consistent	Very large	Indefinite	Imperfect	Conventional
	Entiat	---	None	---	---	Consistent	---	---	---	---
	Methow	Winthrop NFH	Integrated	395 fish collected at Wells Dam	100,000	Inconsistent	Large	Indefinite	Flawed	Conventional
		Wells SFH	Integrated		320,000	Inconsistent	Very large	Indefinite	Flawed	Mixed
	Okanogan	Wells SFH	Integrated		130,000	Inconsistent	Very large	Indefinite	Flawed	Mixed
	Mainstem Columbia	Ringold SFH	Segregated		180,000	Inconsistent	Moderate	Indefinite	Unknown	Conventional

[1] Values given in parentheses are for planned programs that do not exist at present.

[2] Near-term reductions in the program's production objective have been discussed but not implemented.

[a] Programs are transitional, with limited captive brood-based efforts that may expand to the levels of hatchery smolt production indicated.

origin and wild salmon, and none appear to be rearing juveniles using a full suite of progressive rearing techniques so as to minimize artificial selection and reductions of natural fitness in the hatchery environment to the degree practicable. This characterization is true of both integrated and segregated hatchery programs within the Province, though the issue of rearing protocols may be germane only to the integrated programs. Despite these shortcomings, however, the hatchery programs have been and are continuing to make improvements. The monitoring programs in place to assess hatchery effectiveness within multiple subbasins, and particularly the Wenatchee, are substantial.

One of the greatest difficulties here appears to be deciding how to balance conflicting management objectives related to species conservation and to important harvest mitigation. Many hatcheries in the Columbia Cascade Province have moved to incorporate wild broodstock into their programs, but very few have down-sized their production levels to fit their surrounding watersheds as a way to reduce potentially unfavorable impacts on natural salmon populations. The number of programs, their large size, and their relatively close geographic proximity to one another and/or to multiple salmon spawning areas, makes the issue of imperfect control over breeding between hatchery-origin and wild salmon even more important. This is particularly true in the Wenatchee and Methow subbasins. In multiple instances, inadequate infrastructure for ongoing programs is a substantial problem. Selective fisheries have been offered as a possible solution to higher-than-desired escapements of marked hatchery-origin fish from integrated hatchery programs, but this itself raises questions about the magnitude of hatchery releases in situations where the hatchery-origin fish are listed under the ESA.

CONCLUSIONS

ESA-listed spring chinook in the Province are likely losing natural fitness (and thus natural productivity) as a consequence of at least some of the hatchery programs being employed, in part, to offset the effects of the Columbia River hydrosystem. In the case of the area's natural steelhead populations, which have a long history of heavy hatchery supplementation, integrated programs that are not sized to fit the surrounding landscape or that are operating without broodstock specific to their targeted areas seem likely to impede development of stronger runs. If the long-term objective is to restore self-sustaining runs of currently ESA-listed anadromous salmonids to the area, near-term changes toward more tightly controlled hatchery programs, both integrated and segregated, are needed so that ongoing programs will minimize potential unfavorable effects on natural population productivity until downstream problems are remedied.

Given high expectations for fishery mitigation in the Province and the limited space within which to deliver it without potential conflicts with ESA-related conservation efforts, redirecting a sizeable portion of the fish produced by segregated hatchery programs within the Leavenworth Complex away from ESA-listed salmon populations and toward more spatially isolated terminal area fisheries may offer one of the least conflicted solutions. One location that appears suitable for development of such a fishery is the mainstem Columbia near Chief Joseph Dam.

There are also multiple possibilities for using all or portions of one or more of the Leavenworth Complex facilities to provide added low-density and progressive rearing space for integrated hatchery programs already in existence in the Wenatchee, Methow, or Okanogan subbasins. Such shifts would require some changes in hatchery objectives and infrastructure, but might significantly increase the quality of the conservation effort for ESA-listed spring chinook and/or summer steelhead in the Province. The shifts would also require a concerted multi-agency effort to pool hatchery resources, to figure out exactly what ought to be done from a conservation or harvest augmentation standpoint, and how best to do it given the facilities available among all parties.

Fish managers have made a significant commitment to conservation in the Entiat subbasin by making that area a steelhead reserve. Serious consideration should be given to establishing the area as a reserve for all anadromous species.

CITATIONS

Allendorf, F. W., and R. S. Waples. 1996. Conservation and genetics of salmonid fishes. Pages 238-280 in J. C. Avise, ed. Conservation genetics: Case histories from nature. Chapman Hall, New York.

APRE. 2004. Artificial production review and evaluation. Final basin report. Document 2004-17. Northwest Power and Conservation Council, Portland, Oregon. 30 December 2004.

Araki, H., W. R. Ardren, E. Olsen, B. Cooper, and M. S. Blouin. 2006. Reproductive success of captive-bred steelhead trout in the wild: evaluation of three hatchery programs in the Hood River. Conservation Biology.

Berejikian, B. A., and M. J. Ford. 2004. Review of relative fitness of hatchery and natural salmon. NOAA Tech. Memo. NMFS-NWFSC-61. December 2004.

Bowles, E. C. 1995. Supplementation: panacea or curse for recovery of declining fish stocks. *Uses and effects of cultured fishes in aquatic ecosystems* 15:277-283.

Bugert, R. M. 1998. Mechanics of supplementation in the Columbia River. Fisheries 23:11-20.

Chapman, D., C. Peven, T. Hillman, A. Giorgi, and F. Utter. 1994. Status of summer steelhead in the Mid-Columbia river. Don Chapman Consultants Inc. Boise, Idaho. 235 p.

Chapman, D., C. Peven, A. Giorgi, T. Hillman, and F. Utter. 1995. Status of spring chinook salmon in the mid-Columbia region. Don Chapman Consultants Inc. Boise, Idaho. 477 p.

Cooper, Matt, C.O. Hamstreet, and D. Carie. 2006. Fish production review of the Leavenworth National Fish Hatchery Complex, 2005. U.S. Fish and Wildlife Service, Mid-Columbia River Fishery Resource Office, Leavenworth, Washington.

Copeland, T., J. Johnson, and P. R. Bunn. 2005. Idaho natural production monitoring and evaluation, annual report, July 01 2004 - June 30, 2004. IDFG Report 05-38. Idaho Department of Fish and Game. Boise, Idaho.

Cuenco, M. L., T. W. H. Backman, and P. R. Mundy. 1993. The use of supplementation to aid in natural stock restoration. Pages 269-293 in J. G. Cloud and G. H. Thorgaard, eds. *Genetic conservation of salmonid fishes*. Plenum Press, New York.

Flagg, T. A., B. A. Berejikian, J. Colt, W. W. Dickhoff, L. W. Harrell, D. J. Maynard, C. E. Nash, M. S. Strom, R. N. Iwamoto, C. V. Mahnken. 2000. Ecological and behavioral impacts of artificial production strategies on the abundance of wild salmon populations. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-41, 92 p.

Ford, M. J. 2002. Selection in captivity during supportive breeding may reduce the fitness in the wild. Conservation Biology 16(3):815-825.

Ford, M. J., T. A. Lundrigan, and P.C. Moran. 2004. Population genetics of Entiat River spring Chinook salmon. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-60. 45 p.

Ford, M., and 12 co-authors. 2001. Upper Columbia River steelhead and spring chinook salmon population structure and biological requirements. Final report. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Good, T. P., R. S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESUs of salmon and steelhead. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-66.

Goodman, D. 2005. Selection equilibrium for hatchery and wild spawning fitness in integrated breeding programs. Can. J. Fish. Aquat. Sci. 62:374-389.

Hatchery Science Review Group (HSRG) –Mobrand, L., J. Barr, D. Campton, T. Evelyn, T. Flagg, C. Mahnken, R. Piper, P. Seidel, L. Seeb, and B. Smoker. 2004. Hatchery reform: principles and recommendations of the HSRG. Long Live the Kings, Seattle, Washington. (available from www.hatcheryreform.org). November 2004.

Hatchery Science Review Group (HSRG) –Mobrand, L., J. Barr, H. L. Blankenship, D. Campton, T. Evelyn, T. Flagg, C. Mahnken, R. Piper, P. Seidel, L. Seeb, and B. Smoker. 2005. Puget Sound and Coastal Washington Hatchery Reform Project: Progress Report to Congress. Long Live the Kings, Seattle, Washington. (available from www.hatcheryreform.org). April 2005.

Huntington, C., W. Nehlsen, and J. Bowers. 1996. A survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. *Fisheries* 21:6-14.

Independent Economic Analysis Board (IEAB). 2005. Economic effect from Columbia River Basin anadromous salmonid fish production. Document IEAB 2005-1. Revised December 2005.

Independent Science Review Panel (ISRP). 2005. ISRP retrospective report 1997-2005. Northwest Power and Conservation Council, Portland, Oregon. Report ISRP 2005-14. 31 August 2005. 150 p.

Independent Scientific Advisory Board (ISAB). 2003. Review of salmon and steelhead supplementation. Northwest Power Planning Council, Portland, Oregon. Report ISAB 2003-3. 255 p.

Independent Scientific Group (ISG). 2000. Return to the river: Restoration of salmonid fishes in the Columbia River ecosystem. Northwest Power Planning Council, Portland, Oregon.

Interior Columbia Basin Technical Recovery Team (ICBTRT). 2005. Interior Columbia Basin TRT: Viability criteria for application to Interior Columbia Basin Salmonid ESUs. NOAA National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington. July 2005 document plus update memo dated December 2005.

ICBTRT. 2006. Required survival rate changes to meet Technical Recovery Team abundance and productivity viability criteria, Interior Columbia populations. ICBTRT Interim Gaps Report. NOAA National Marine Fisheries Service, Nothwest Fisheries Science Center, Seattle, Washington. 17 May 2006.

Kostow, K. E. 2004. Differences in juvenile phenotypes and survival between hatchery stocks and a natural population provide evidence for modified selection due to captive breeding. Can. J. Fish. Aquat. Sci. 61:577-589.

Lynch, M., and M. O'Hely. 2001. Captive breeding and genetic fitness of natural populations. Conservation Genetics 2:363-378.

Meyers, R. A., S. A. Levin, R. Lande, F. C. James. W. W. Murdoch, and R. T. Paine. 2004. Ecology, hatcheries, and endangered salmon. Science 303:1980.

National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife, Confederated Tribes of the Yakama Indian Nation, Confederated Tribes of the Colville Indian Reservation, Confederated Tribes of the Umatilla Indian Reservation, Chelan County Public Utility District, and Douglas County Public Utility District. 1998. Biological Assessment and Management Plan: Mid-Columbia River Hatchery Program. Chelan County Public Utility District, Wenatchee, Washington.

National Marine Fisheries Service (NMFS). 2000. Endangered Species Act – Section 7 Consultation, Biological Opinion: Reinitiation of consultation on operation of the federal Columbia River power system, including the juvenile fish transportation program and 19 Bureau of Reclamation projects in the Columbia Basin. National Marine Fisheries Service, Northwest Region. 21 December 2000.

National Research Council (NRC). 1996. Upstream: salmon and society in the Pacific Northwest. Report on the Committee on Protection and Management of Pacific Northwest Anadromous Salmonids for the National Research Council of the National Academy of Sciences. National Academy Press, Washington D. C.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. *Fisheries* 16:4-21.

Nickelson, T. E., M. F. Solazzi, and S. L. Johnson. 1986. Use of hatchery coho salmon (Oncorhynchus kisutch) presmolts to re-build wild populations in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 43:2443-2449.

Northwest Power Planning Council (NPPC). 2000. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council. Portland, Oregon.

Oosterhout, G. R., C.W. Huntington, T. E. Nickelson, and P.W. Lawson. 2005. Potential benefits of a conservation hatchery for supplementing Oregon Coast coho salmon (Oncorhynchus kisutch) populations: a stochastic model investigation. Can. J. Fish. Aquat. Sci. 62:1920-1935.

Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW). 2006. Joint staff report concerning commercial seasons for spring chinook, steelhead, sturgeon, shad, smelt, and other species and miscellaneous regulations for 2006. Joint Columbia River Management Staff, ODFW and WDFW. 18 January 2006.

Pacific Salmon Commission Joint Chinook Technical Committee (PSC). 2005a. Catch and escapement of chinook salmon under Pacific Salmon Commission jurisdiction, 2004. Report TCCHINOOK (05)-2. Pacific Salmon Commission. 26 October 2005.

Pacific Salmon Commission Joint Chinook Technical Committee (PSC). 2005b. Annual exploitation rate analysis and model calibration. Report TCCHINOOK (05)-2. Pacific Salmon Commission. 28 December 2005.

Palmisano, J. F., R. E. Ellis, and V. W. Kaczynski. 1993. The impact of management and environmental factors on Washington's anadromous salmon and trout. Report prepared for the Washington Forest Protection Association and the State of Washington Department of Natural Resources, Olympia, Washington. January 1993.

Petrosky, C.E., H.A. Schaller, and P. Budy. Productivity and survival rate trends in the freshwater spawning and rearing stage of Snake River chinook salmon (Oncorhynchus tshawytscha). Can. J. Fish. Aquat. Sci. 58:1196-1207.

Rahr, G. R., J. A. Lichatowich, R. Hubley, and S. M. Whidden. 1998. Sanctuaries for native salmon: a conservation strategy for the 21st century. *Fisheries* 23:6-8.

Raymond, H. L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. North American Journal of Fisheries Management. 8:1-24.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. *Transactions of the American Fisheries Society* 108:505-529.

Salmon Recovery Science Review Panel (RSRP). 2004. Report for meeting held 30 August – 2 September 2004. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Scientific Review Team (SRT). 1999. Review of salmonid artificial production in the Columbia River basin as a scientific basis for Columbia River production programs. Northwest Power Planning Council. Portland, Oregon. 77 p.

Upper Columbia Regional Technical Team (UCRTT). 2002. A biological strategy to protect and restore salmonid habitat in the Upper Columbia region. Discussion Draft. June 2002.

Upper Columbia Salmon Recovery Board (UCSRB). 2006. Proposed Upper Columbia spring chinook salmon, steelhead, and bull trout recovery plan. June 2006.

Waknitz, F. W., G. M. Matthews, T. Wainwright, and G. A. Winans. 1995. Status review for mid-Columbia River summer chinook salmon. U.S. Dept. Commer., NOAA Tech Memo. NMFS-NWFSC-22, 80 p.

Waples, R. S. 1999. Dispelling some myths about hatcheries. Fisheries 24:12-21.

Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW). 2002. Status report: Columbia fish runs and fisheries, 1938-2000. 324 p.

WDFW. 2002. 2002 Salmonid Stock Inventory (SaSI) database. Information available at: wdfw.wa.gov/fish/sasi/.

WDFW. 2005. Multiple DRAFT hatchery and genetic management plans for programs in the Columbia Cascade Province. Washington Department of Fish and Wildlife, Olympia.

WDFW. 2006. Harvest framework for non-treaty fisheries directed at salmonids originating above Priest Rapids Dam. DRAFT. April 2006.

White, R. J., J. R. Karr, and W. Nehlsen. 1995. Better roles for fish stocking in aquatic resource management. Uses and effects of cultured fishes in aquatic ecosystems 15:527-547.

Williams, R.N., J.A. Lichatowich, P.R. Mundy, and M. Powell. 2003. Integrating artificial production with salmonid life history, genetic, and ecosystem diversity: a landscape perspective. Issue Paper for Trout Unlimited, West Coast Conservation Office, Portland. 04 September 2003.

APPENDIX A – Selected Information on the Province's Integrated Hatchery Programs and On Recent and Historic Smolt Production Potentials

Table A1. Broodstock, smolt production, estimated smolt-to-adult-return (SAR), and approximate spawner-recruit performance for the integrated Chiwawa/Eastbank spring chinook stock, brood years 1989-1999.

	Number of fish taken for hatchery program[1]				Estimated adult returns (data source: RMIS)[3]					
					Smolt-to-adult-return		Adult return		Recruits/Spawner	
Brood year	Broodstock	Eggs	Release year	Smolts[2]	Total	Chiwawa	Total	Chiwawa	Total	Chiwawa
1989	53	38,000	1991	42,999	0.43%	0.132%	185	57	3.5	1.1
1990	38	50,000	1992	53,170	0.04%	0.002%	21	1	0.6	0.03
1991	33	62,600	1993	62,138	0.17%	0.139%	106	86	3.2	2.6
1992	113	90,100	1994	85,113	0.03%	0.003%	26	3	0.2	0.02
1993	109	202,500	1995	223,610	0.13%	0.093%	291	208	2.7	1.9
1994	15	35,871	1996	27,226	0.07%	0.065%	19	18	1.3	1.2
1995	0	0	1997	0	---	---	---	---		---
1996	15	18,000	1998	15,176	0.52%	0.431%	79	65	5.3	4.4
1997	119	307,500	1999	266,148	0.99%	0.579%	2635	1541	22.1	12.9
1998	48	126,000	2000	75,906	1.52%	0.871%	1154	661	24.0	13.8
1999	0	0	2001	0	---	---	---	---	---	---
2000	35	49,500	2002	47,104	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2001	380	1,059,000	2003	377,544	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2002	95	185,100	2004	149,668	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2003	188	155,500	2005	222,131	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2004	359	558,000	2006	494,517	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2005	283	592,500	2007	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2006	424	777,500	2008	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*

[1] -- Per annual WDFW hatchery return reports.

[2] -- Per the Fish Passage Center.

[3] -- Adult return data are approximate and based on coded-wire tag information.

Table A2. Broodstock, egg collection, and smolt release data for integrated spring chinook hatchery programs in the Methow system, brood years 1992-2006.

Brood	Numbers of fish collected by WDFW for the hatchery program, by collection site[1]										Release	ESA-listed smolts released, by location[2]			
	Adult broodstock					Eggs (collected from the adult broodstock)									
year	Methow	Chewuch	Twisp	Wells	Total	Methow	Chewuch	Twisp	Wells	Total	year	Methow	Chewuch	Twisp	Total
1992	---	20	30	---	50	---	47,000	36,000	---	83,000	1994	0	40,882	35,881	76,763
1993	98	26	36	---	260	196,000	232,000	92,000	---	520,000	1995	210,489	284,165	116,749	611,763
1994	17	7	5	---	29	48,802	21,191	13,469	---	83,462	1996	4,477	11,854	19,835	36,166
1995	10	---	---	---	10	31,500	---	---	---	31,500	1997	14,258	0	0	14,258
1996[a]	---	---	---	399	399	---	---	---	624,400	624,000	1998[a,b]	527,798	91,672	76,687	696,157
1997[a]	---	---	---	322	322	---	---	---	728,000	728,000	1999[a,b]	877,546	132,759	26,714	1,037,019
1998[a]	---	---	---	410	410	---	---	---	774,000	774,000	2000[a]	218,499	217,171	15,470	451,140
1999[a]	---	---	---	256	256	---	---	---	607,500	607,500	2001[a,b]	356,644	0	67,408	424,052
2000[a]	162	---	---	344	506	---	---	---	---	773,800	2002[a,b]	201,604	266,392	80,392	548,388
2001	682	65	41	---	788	592,000	128,000	124,500	---	841,020	2003[b,c]	392,209	261,284	57,471	710,964
2002	1558	6	1	---	1565	1,373,032	0	0	---	1,373,032	2004[b,c]	718,765	254,238	58,074	1,031,077
2003	217	3	---	---	220	368,000	8,000	---	---	376,000	2005[b,c]	433,434	127,614	99,933	660,981
2004	227	11	82	---	320	580,000	4,000	144,000	---	728,000	2006[b,c]	550,146	204,906	96,617	851,669
2005	215	11	14	---	240	372,000	12,000	28,000	---	412,000	2007	*N/A*	*N/A*	*N/A*	*N/A*
2006[d]	188	---	---	182	370	367,500	---	---	308,000	675,500	2008	*N/A*	*N/A*	*N/A*	*N/A*

[1] -- Per annual WDFW hatchery return reports.

[2] -- Per the Fish Passage Center.

[a] -- Adults were trapped at Wells Dam and assigned to their home river with an ~40% error rate, future lineages affected.

[b] -- Methow releases of ESA-listed fish reared at Winthrop NFH are included; in some years these releases included the offspring of adults not collected by WDFW.

[c] -- Fish released into the Methow and Chewuch were of a composite stock whose lineage was combined for the two systems.

[d] -- Collections of adults were reinitiated at Wells Dam due to declining adult returns and high spring flows that hampered the ability to trap them farther upstream.

Table A3. Estimates of recent and historic smolt production capacities for multiple species of anadromous salmonids in the Wenatchee, Entiat, Methow, and Okanogan subbasins.

Subbasin	Species	Recent smolt production capacity	Historic smolt production capacity
Wenatchee	Spring chinook	287,600[a]	635,600[b]
	Summer chinook	1,222,000[c]	---
	Summer steelhead	86,000[a]	172,300[b]
	Sockeye	5,600,000[d]	5,600,000[d]
	Coho	---	78,000[e]
Entiat	Spring chinook	37,000[a]	---
	Summer chinook	54,700[c]	---
	Summer steelhead	17,500[a]	---
	Coho	---	90,000[e]
Methow	Spring chinook	231,200[a]	462,500[b]
	Summer chinook	614,000[c]	---
	Summer steelhead	123,900[a]	172,200[b]
	Coho	---	720,000[e]
Okanogan (U.S. portion)	Spring chinook	---	---
	Summer chinook	596,000[f]	---
	Summer steelhead	35,100[a]	111,300[b]
	Sockeye	---	---
	Coho	---	---

[a] -- Average of five or more estimates from Ford et al. (2001), UCSRB (2006), and others.
[b] -- Recent capacity adjusted in proportion to EDT-based estimates of percent loss, per UCSRB (2006).
[c] -- Average of multiple estimates by Mullan et al. (1992).
[d] – Mean of recent relatively consistent WDFW estimates of sockeye smolt production in Lake Wenatchee reported by Seiler et al. (2004) and Volkhardt et al. (2005).
[e] -- Historic adult abundance estimated by Mullan et al. (1992) divided by 5% smolt-to-adult survival.
[f] -- Smolt Density Model (SDM) estimate (MMFS et al. 1998) adjusted by the mean ratio between SDM and Mullan et al. (1992) estimates for the Wenatchee and Methow systems.

Table A4. Rough, first-cut estimates of the historic Columbia River Basin production of anadromous salmonid smolts.

Species	Middle Columbia[2]	Columbia abv. Snake	Snake blw. Hells Cyn	Snake abv. Hells Cyn	Columbia Basin above Bonneville
	Historically accessible habitat above the site of Bonneville Dam (sources: NRC 2005; NPPC 1986)[1]				
Spring chinook	1,218	1,801	3,899	1,865	8,783
Summer chinook	148	909	2,198	1,865	5,120
Fall chinook	201	485	674	371	1,731
Sockeye	250	215,878	5,222	1,500	222,850
Coho	344	523	481	0	1,348
Chum salmon	---	---	---	---	---
Steelhead	1,834	1,485	5,156	2,050	10,525

[1] Quantities given in stream miles except for sockeye, for which they are in acres of rearing lakes.

[2] Minor adjustments made to correct juxtaposed values given in NPPC (1986).

Species	Columbia blw Bonneville	Middle Columbia	Columbia abv. Snake	Snake blw. Hells Cyn	Snake abv. Hells Cyn	Entire Columbia Basin
	Estimated historical production of wild salmon and steelhead adults[3]					
Spring chinook	101,000	68,784	101,707	220,187	105,322	597,000
Summer chinook	0	73,335	450,417	1,089,126	924,122	2,537,000
Fall chinook	772,000	101,023	243,761	338,752	186,464	1,642,000
Sockeye	0	3,189	2,754,055	66,619	19,136	2,843,000
Coho	424,000	122,237	185,843	170,919	0	903,000
Chum salmon	536,000	---	---	---	---	536,000
Steelhead	103,000	81,376	65,890	228,775	90,960	570,000
Totals	1,936,000	449,944	3,801,674	2,114,379	1,326,004	9,628,000

[3] Estimates for the entire Columbia Basin from NPPC (1986) were distributed among basin areas in direct proportion to the habitat quantities given earlier in the table after first splitting production for areas above and below Bonneville as per Chapman (1985).

Species/age	Columbia blw Bonneville	Middle Columbia	Columbia abv. Snake	Snake blw. Hells Cyn	Snake abv. Hells Cyn	Entire Columbia Basin
	Estimated historical production of wild salmon and steelhead juveniles (smolts)[4]					
Chinook yearlings	1,010,000	2,109,027	2,034,148	15,295,005	11,347,654	31,795,834
Chinook subyearlings	41,125,000	6,884,505	34,708,872	44,165,763	12,970,510	139,854,650
Sockeye yearlings	0	63,787	55,081,100	1,332,389	382,724	56,860,000
Coho yearlings	8,480,000	2,444,748	3,716,869	3,418,383	0	18,060,000
Chum fry	---	---	---	---	---	---
Steelhead overyearlings	2,060,000	1,627,512	1,317,805	4,575,491	1,819,192	11,400,000
Yearlings	11,550,000	6,245,074	62,149,922	24,621,268	13,549,570	118,115,834
Subyearlings	41,125,000	6,884,505	34,708,872	44,165,763	12,970,510	139,854,650
Totals	***52,675,000***	***13,129,579***	***96,858,794***	***68,787,031***	***26,520,080***	***257,970,484***

[4] Assumes a conservative 2% SAR for subyearling smolts and a 5% SAR for yearling/overyearling smolts.

APPENDIX B – Additional Information Used in Assessing Hatchery Programs in the Columbia Cascade Province

Compilations of additional information used in the assessment are available on request.